

Graduate School of Frontier Sciences, The University of Tokyo
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Master's Thesis

**Distribution and Habitat of Seabuckthorn (*Hippophae* L.) in
Northwest Nepal**

ネパール北西部におけるヤナギハグミ属 (*Hippophae* L.) の分布とハビタット

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September 2007 Institute of Environmental Studies, Course of natural Environmental Studies

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Supervisor: Dr. Kenji Fukuda, Professor

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1. Introduction

Seabuckthorn (*Hippophae* L.) is a multidimensional plant species naturally distributed in the temperate regions of Eurasia. It is one of the potential plants, the sustainable uses and management of which can be beneficial for combating threats on the environment and biodiversity of rural area of Nepal. Moreover, the product of seabuckthorn could also be helpful for the economic development and poverty alleviation. *Hippophae rhamnoides* is the popular, well-studied and widely distributed species of seabuckthorn, however other species are rarely known. There are two species of seabuckthorn in Nepal; *H. salicifolia* and *H. tibetana*. *H. salicifolia* is a tree or bush with long slender willow-like branches and few thorns. *H. tibetana* is a shrub with a thick tortuous knobby stem and abundant upright shoots ending in thorns. This study is aimed to explore the distribution of two species of seabuckthorn viz. *H. salicifolia* and *H. tibetana* in Nepal and to determine the habitat of these species.

2. Study area and methods

This study was carried out in the Mustang district, the northwest part of Nepal which is surrounded by the Tibetan plateau to north. Due to the variation in the altitude, it harbors diverse type of flora and fauna. Although the area is rich in biodiversity, researches in this area have been quite restricted by political and geographical difficulties.

To study the distribution pattern, habitat of seabuckthorn was visited based on local information, and habitat such as altitude, aspect, slope, longitude, latitude, and associated species were noted by field observation. Vegetation and soil survey were conducted in Mustang district during august 2006. Three plots were set along the 100 m- long transect in each of three sites for each species. The size of plot was 10 m × 10 m for *H. salicifolia* and 5 m × 5 m for *H. tibetana*. Height and DBH of tree were measured. Diameter at the ground level and height were measured for shrubs. The herbs were measured by recording maximum height of each species and their coverage. Surface soil of 0-5 cm depth was taken from each plot to analyze the physical and chemical characteristics.

3. Results and Discussion

The result of distribution of seabuckthorn in northwest Nepal revealed that the habitat for natural population of *H. salicifolia* is riverbank, mountain slope and mountain gullies from 2000 to 3850 m.a.s.l and for *H. tibetana* is plain land near water bodies from 2900 to 4500 m.a.s.l. *Pinus wallichiana* and *Prinsepia utilis* are the major associates of *H. salicifolia* and *Caragana brevispina* and *Myricaria germanica* are of *H. tibetana*. Diversity of life form decreases with increasing altitude i.e. diversity of plant life form was high in *H. salicifolia* sites as compared to *H. tibetana* site. Majority of plants recorded in the investigated plots belonged to disseminule form D4: without special mechanism for seed dispersal.

The tree size of *H. salicifolia* was smaller in the lower Plot 1 (riverside) than middle slope (Plot 2), and seabuckthorn were replaced by *Pinus wallichiana* in the upper slope (Plot 3) (Fig. 1). In *H. tibetana* sites, on the contrary had high diameter and height class individuals' then middle slope and few dwarf shrubs and

herbs in the upper slope. Texture of soil in the majority of plot was sandy loam that is poor in water and nutrient holding capacity. In *H. salicifolia* site, the amount of soil nutrients (carbon, nitrogen, phosphorus and potassium) was increased along the slope from Plot 1 to Plot 3 (Fig. 2). On the other hand, the trend was opposite in *H. tibetana* sites. The increase in the amount of soil nutrients along the slope is in accordance with the increase in basal area (biomass) in each plot.

In conclusion, *H. salicifolia* was found to be a pioneer tree in a river bank after flooding and landslide and to be replaced by *Pinus wallichiana* forest. On the other hand *H. tibetana* is a late successional shrub in subalpine region and prefer fertile soil than its associate plants.

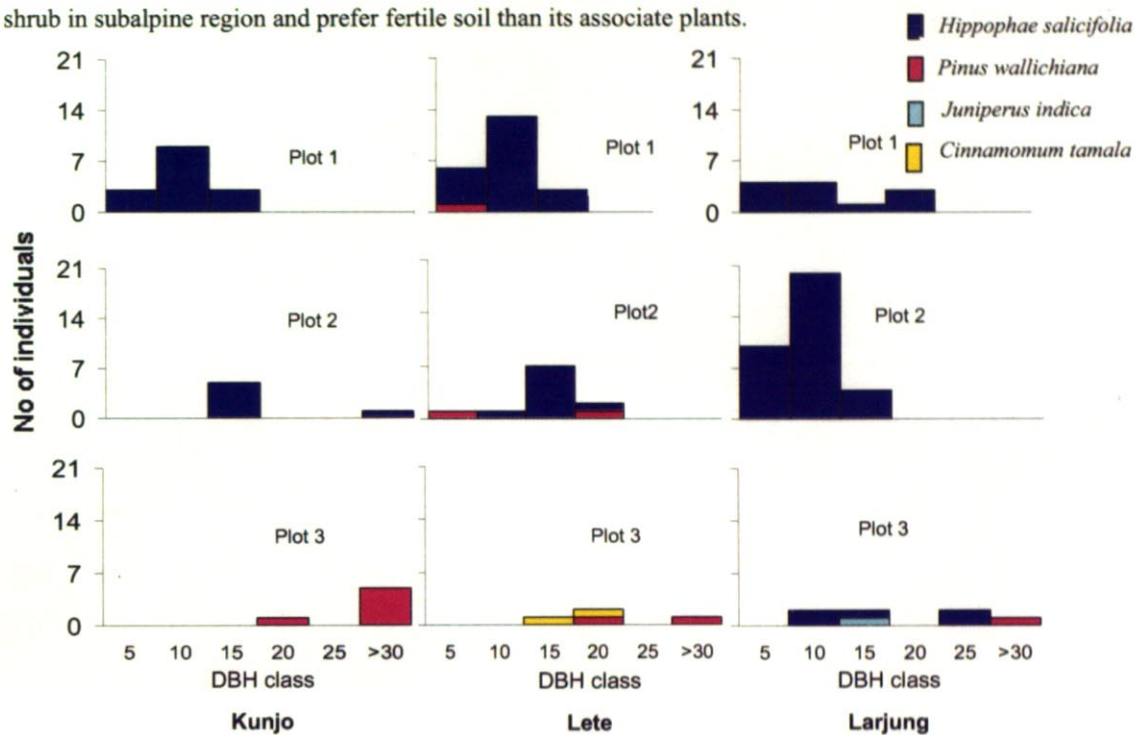


Fig.1: DBH- class distribution of tree in *Hippophae salicifolia* sites

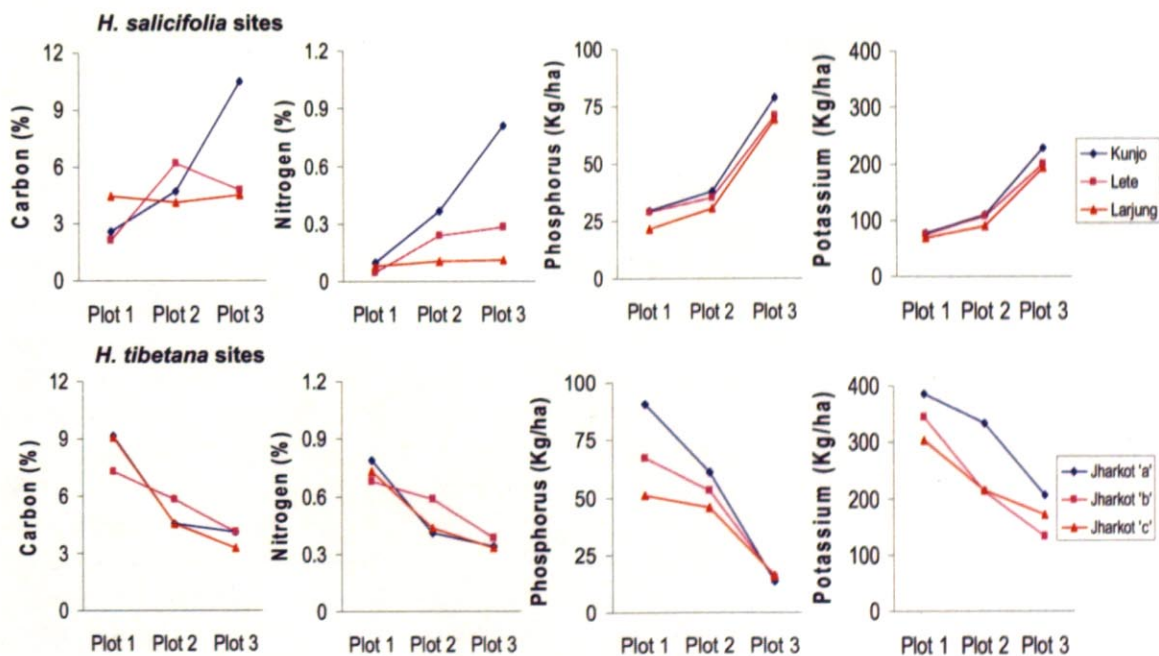


Fig 2: Plot wise nutrient condition of soil

ネパール北西部におけるヤナギハグミ属 (*Hippophae* L.) の分布とハビタット

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1. はじめに

ヤナギハグミ属 (*Hippophae* L.) は、ユーラシア地域の温帯に分布する多用途植物である。ネパールでは、ヤナギハグミ製品が経済発展や貧困緩和に役立つことが期待されていることから、分布域と生育可能な環境条件を知る必要がある。*Hippophae rhamnoides* は分布域が広く既往研究が多いが、それ以外の種に関してはほとんど調べられていない。ネパールには、*H. Salicifolia* と *H. tibetana* の 2 種類のヤナギハグミが分布する。*H. salicifolia* は高木または灌木で、*H. tibetana* は矮性灌木で幹は湾曲し凹凸がある。植物の生育地は、生物気候的、歴史的な分布要因だけでなく、個々の立地、土壌などの条件によって決定されることが考えられる。そこで本研究では、ネパール北西部における、*H. salicifolia* と *H. tibetana* の分布とそれぞれのハビタットを明らかにすることを目的とした。

2. 調査地および方法

本研究の対象地域は、ネパール北部に位置する Mustang 地区であり、北部にはチベット高原が広がっている。様々な標高域に多様な植物・動物相が存在しているため、生物多様性が高い地域であるが、政治的、地理的な要因によって調査が制限されている。

まず、ネパール北西部の一般的なヤナギハグミの分布パターンを調べるため、標高、斜面方位、傾斜、緯度、経度などの生息地の環境を現地調査によって調べた。次に、2006 年 8 月に *H. salicifolia*, *H. tibetana* それぞれについて 3 つの生育地を選び、地形傾度に沿った 3 プロット、合計 18 プロットにおいて植生調査と土壌サンプル採取を行った。各サイトにおいて、川岸の斜面下部から上部にかけて 100 m のトランセクトに沿って 3 プロットを配置した。プロットのサイズは、*H. salicifolia* は 10 m×10 m、*H. tibetana* は 5 m×5 m である。高木は、樹高と胸高直径 (DBH) を測定し、樹高階分布と胸高直径階分布を作成した。灌木は樹高と地際直径を測定し、草本は最大自然高と被度を測定した。各プロットの植生に関して、ラウンケルの生活形と沼田の散布型を調べた。土壌の物理性と化学性を調べるために、各プロットにおいて 0~5 cm の深さの土壌を採取した。

3. 結果と考察

ネパール北西部におけるヤナギハグミの自然個体群の分布域が明らかとなった。*H. salicifolia* は標高 2000~3850 m の川岸、山腹、侵食谷に分布し、*H. tibetana* は標高 2900~4500 m の地表水面に近い平地に分布することがわかった。*H. salicifolia* に付随して主に *Pinus wallichiana* や *Prinsepia utilis* が生育しており、*H. tibetana* には主に *Caragana brevispina* や *Myricaria germanica* が付随して生育していた。生活形の多様性は標高が上がるにつれて減少し、*H. salicifolia* サイトの生活形は *H. tibetana* サイトに比べて多様性が高かった。主な植物は D4 型で、種子散布の特別なメカニズムは発達していなかった。

H. salicifolia のサイトでは、川岸の下部斜面プロット (Plot 1) は樹高・DBH クラスが中部傾斜プロット (Plot 2) に比べて小さく、上部斜面プロット (Plot 3) では、*Pinus wallichiana* が優占する植生になっていた (図 1)。一方、*H. tibetana* のサイトでは、下部斜面プロットの樹高・DBH クラスが高く、上部斜面プロットはわずかに矮性灌木や草本が生育しているのみであった。

土性は主に砂質壤土で、水分、養分が少なかった。*H. salicifolia* サイトにおいて、土壌養分 (炭素、窒素、リン、カリウム) は斜面の下部 (Plot 1) から上部 (Plot 3) になるにつれて増加した (図 2)。一方、*H. tibetana* のサイトでは、逆の傾向が見られた。土壌養分の上昇に伴って、

胸高断面積（バイオマス量）も増加していた。

これらの結果から、*H. salicifolia* は攪乱直後の先駆種として溪畔の不安定な土壌に生育し、斜面上部の安定した肥沃な土壌ではマツ林へと遷移していると考えられる。一方、*H. tibetana* は高山帯に分布し、矮性植物群落の中で比較的発達した植生として、水分、養分の多い斜面下部に分布することが明らかになった。

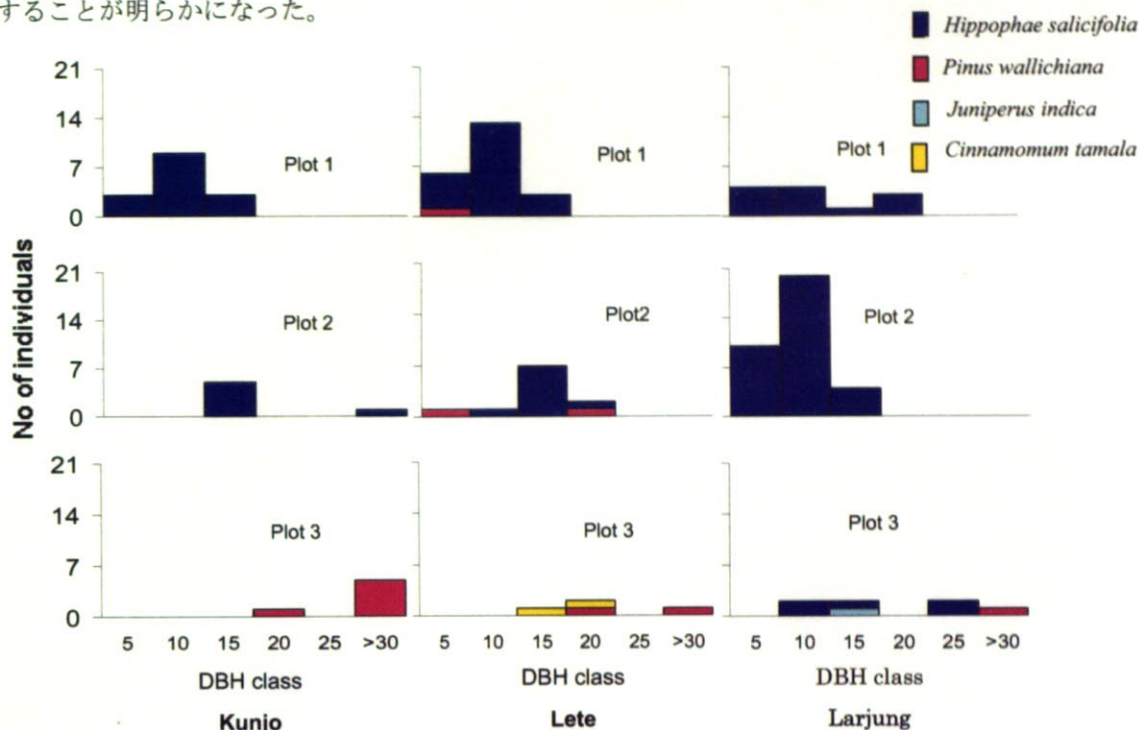


図1 *Hippophae salicifolia* の胸高直径階分布

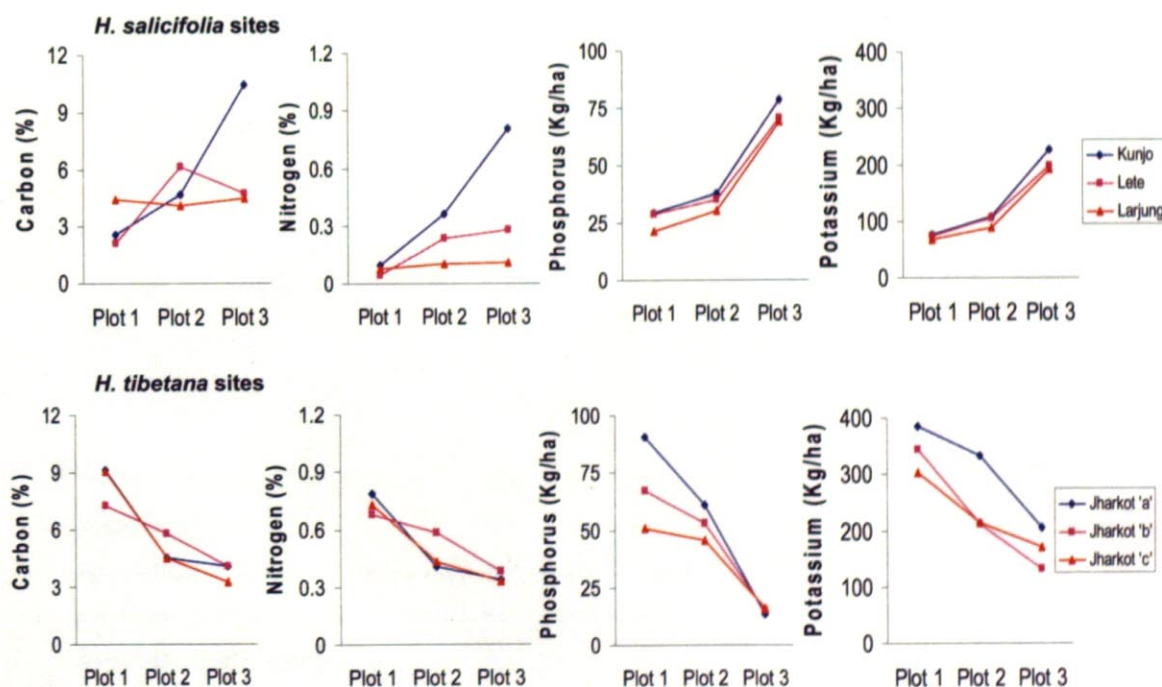


図2 各プロットの土壌養分含有量

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1. Introduction

1.1 Background

Mountain ecosystems are extremely fragile and provide tremendous ecological services to the planet. They cover one fourth of the world's forest and also store the biological diversity that is necessary for the sustainability of human life. But, they are susceptible to soil erosion, landslides, anthropogenic disturbance and loss of genetic diversity (ICIMOD 2007).

Nepal with an area of 147,181 km² is a magnificent country in the central Himalaya with varying altitudes, climates and geological conditions. Owing to a wide variation of physiography, climate and edaphic condition in Nepal, the habitat changes abruptly, and almost all climatic zones of the world are represented in a comparatively small area with different vegetation types. In Nepal, forests and other natural vegetation have been used extensively for timber, fodder, firewood, leaf litter, medicines, foods, spices, fibers, tannins, gums, resins, fatty oils, dyes, incense, cosmetics, building materials and agricultural implements (Subedi 2004).

Habitat loss, forest destruction and degradation, population growth, poverty, soil erosion, overexploitation of forest resources and illegal trade are the major threats on environment and biodiversity of Nepal (Chaudhary 2000). Save it, know what it is and use it sustainably are the three major steps in the conservation of biodiversity (Janzen 1992). Thus knowledge on ecology, distribution and uses of element of biodiversity are essential to get the sustainable benefit from the resources. Seabuckthorn (*Hippophae* Linn.) is one of the potential plants, the sustainable uses and management of which could be beneficial for combating threats on the environment and biodiversity of rural area of Nepal. Besides this, the products of seabuckthorn could also be helpful for the economic development and poverty alleviation to some extent.

1.2 Seabuckthorn (*Hippophae* L.)

Hippophae L. is a multidimensional plants belonging to the family Elaeagnaceae. It is a colonizer of open habitat and typically grows on slopes, riverbanks, landslides and seashores. It is an actinorhizal plant that can fix atmospheric nitrogen with the help of Actinomycetes *Frankia* which is present symbiotically in the root nodule.

1.2.1 Taxonomy

They are spiny deciduous shrubs or small trees. Leaves are entire, lower surface is densely stellate or peltate hairy; subsessile to petiolate. Dioecious; flowers are grouped at base of lateral shoots. Male flowers are in small catkins that appear before the leaves; perianth segments 2; stamens 4; disc is small. Female flowers are in small racemes, appearing with the leaves; perianth segments fused, 2-lobed; style stigmatic on one side. Fruits are globose or elliptic berries.

Arne Rousi (1971) recognized three species; *H. rhamnoides* (with nine subspecies), *H. salicifolia* and *H. tibetana*. Later taxonomic studies on seabuckthorn revised the previous one, and new system was proposed where 15 taxa of *Hippophae* L. (*H. rhamnoides* with eight subspecies,

H. goniocarpa with two subspecies, *H. neurocarpa* with two subspecies, *H. gyantsensis*, *H. salicifolia* and *H. tibetana*) was recognized (Lian *et al* 1998, 2003; Bartish *et al.* 2002). Among the taxa, *H. rhamnoides* has the widest distribution throughout Eurasia.

1.2.2 Distribution

It is known that the seabuckthorn originated in the Himalayan mountain regions, and then spread to other parts of the world. A general look at the global distribution pattern of seabuckthorn indicates that it is concentrated in the Hindukush- Himalayan region, adjoining areas of China, parts of Europe and former USSR as well as Scandinavian region (42 countries) (Fig. 1). All of these areas are climatically cold- temperate. This plant has also been introduced to North America (Li 1999).

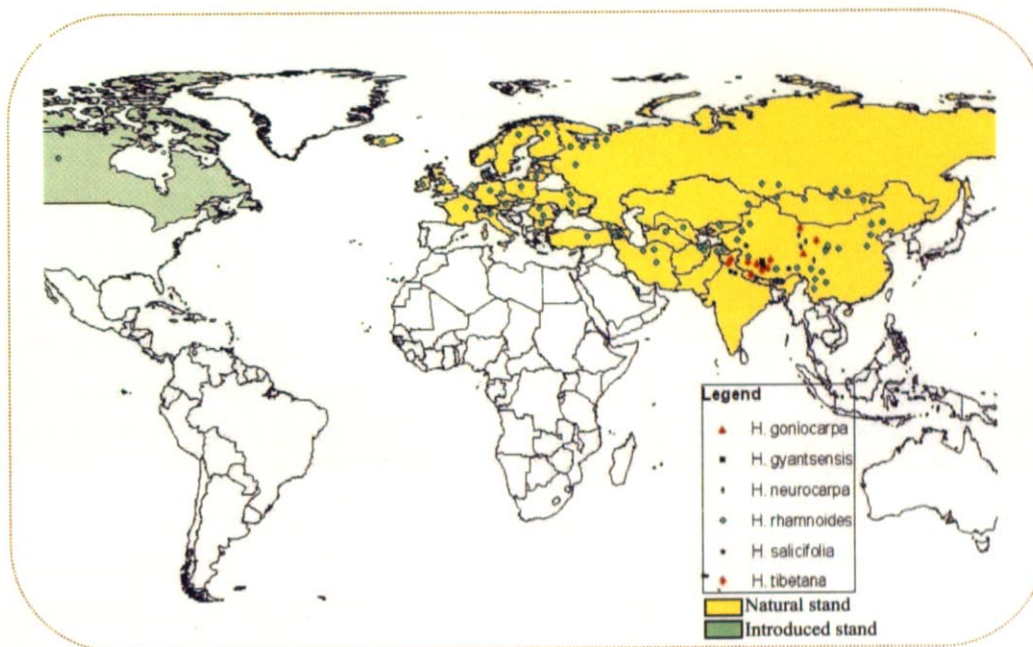


Fig. 1: Distribution of Seabuckthorn in the world

Among different forest types of Nepal, seabuckthorn was kept under the type *Hippophae* scrub (Stainton 1972). The forest type comprised of *H. salicifolia* and *H. tibetana*, where the former plant is confined to lower altitude than the latter. The national herbarium of Nepal (KATH) has collection of seabuckthorn from 12 districts (Fig. 2). Besides Nepal, these species are found in China, India and Bhutan.



Fig. 2: Distribution of seabuckthorn in Nepal

1.2.3 Environment

It occurs throughout the various physical environment of Eurasia and survives in the different climatic conditions. It belongs to the group of thermophilic plants that requires high temperature during seed germination as compared to seeds from the plants grown on the same environment. The adult seabuckthorn plant can endure the temperature of -40°C during winter. Its natural habitat includes riverbanks, valleys and shady slopes of mountains. Although it prefers to grow near water body, its small and narrow leaves with thick cuticle and thorns on stems give it some xerophytic characteristics. Seabuckthorn grows in well drained soil on the bank of river, lakes and seashores. The soil pH value ranges from 5.5 to 8.3 and this variation in soil pH indicates that the acidity and alkalinity of soil is not a limiting factor for seabuckthorn (Lu 1992).

1.2.4 Importance

Owing to its wide distribution, *H. rhamnoides* attracts the attention of the scientific community and development practitioners of the world, and thus research and development have been focused on the utilization of the various dimension of this species.

In ancient Greece, seabuckthorn was known as remedy of horses. Leaves and young branches were added to the fodder that resulted in rapid weight gain and a shiny coat in horse. This in fact gave the name to the plant, in Latin 'Hippo' means horse and 'phaos' means to shine (Lu 1992). Chemical analytical data show that seabuckthorn fruit is rich in nutrients such as carbohydrates, organic acids, amino acids and vitamins. Berries of seabuckthorn are processed into various products such as juice, marmalade and used for flavoring of dairy products because of their unique taste (Gao *et al.* 2000). Oleoresins from fruits are used as food additives, cosmetic ingredients and nutraceuticals (Adela *et al.* 2005). The leaves are rich in protein, fat, vitamins and

fibers that could provide resources of fodder for animals (Singh *et al.* 1995; Lu *et al.* 1998). The leaves can also be used as tea.

Medicinal value of seabuckthorn has already been accounted in the Tibetan medicinal classic 'rGyud bzi' (i.e. the four books of pharmacopoeia) (Lu 1992). The bioactive substances and flavonoids present in the leaves, fruits and seeds can be used to cure various diseases. Several medicinal preparations have been clinically used to treat radiation, damage, burns, oral inflammation and gastric ulcers in China and former Soviet Union. Seabuckthorn contains biologically active substances with pharmacological effects on the cardiovascular, immune system, anti-senile, anti-inflammatory and anti-radiation effect (Xu *et al.* 1998). The hexane extract of *H. rhamnoides* fruits was found to be active in preventing gastric injury (Süleyman *et al.* 2001). The leaves extract of seabuckthorn has a significant anti-inflammatory activity and has potential for the treatment of arthritis (Ganju *et al.* 2005). The seed extract of *H. rhamnoides* has antioxidant and antibacterial properties, indicating the possibility of using the seeds for medicinal use and food preservative (Negi *et al.* 2005). Seabuckthorn in Nepal is known for 'Chuk' which means traditional vinegar. Locally processed juice can be stored for long time and used for pickle making. People of Mustang have begun to sell its product (mainly juice) in the local market. Local Amchis (traditional Tibetan doctors) used the root and fruits of seabuckthorn for the preparation of medicine to cure stomachache, toothache and fever.

The wide adaptation, fast growth, strong coppicing and suckering habits coupled with efficient nitrogen fixation make seabuckthorn well adapted for soil conservation, soil improvement and marginal land reclamation. Windbreaks made up of seabuckthorn are effective at preventing wind erosion in open areas. *H. rhamnoides* is pioneer of planting in loess plateau of China, and also is good shrub to mix with grass and shrubs. It has significant place and role in the course of restoring vegetation of loess plateau and it has the higher comprehensive utilization. These open up a new route for managing Loess Plateau, improving ecological environment, fastening the ending poverty and bring about the prosperity in poverty-stricken regions (Ruan and Li 2002). Seabuckthorn is better suited for semi-arid region of Loess plateau. Therefore, seabuckthorn woodlands in barren hills and gullies in the semiarid region of the Loess Plateau can utilize water and soil resources effectively, which is also an effective way to improve land productivity and to speed up control of the barren hills (Li 1999).

1.3 Factors for plant distribution

Plant distributions are affected by a number of factors. For over a century, ecologists have attempted to determine the factors that control plant species distribution and variation in vegetation composition. Climate is generally accepted as the dominant factor which includes temperature and precipitation. The other climatic factors include day length, light intensity, humidity and wind. Besides climatic factors, distribution of vegetation is also influenced by land use habitat, herbivory, soil and nutrients. The distribution of vegetation is closely related to variety

of climates and soil distribution (Jhang 2002). The analysis of species environment relationship has always been a central issue in ecology (Antoine and Niklaus 2000). Holt *et al.* (1997) concluded that a combination of local and regional effects on population growth rate would result in a positive correlation between abundance and distribution. Factors that potentially affect species distributions have been shown to vary with topographic position, soil water availability (Becker *et al.* 1988), pH and cation exchange capacity (Silver *et al.* 1994). Land use, management variables, soil conditions, hedgerow type and origin have larger influence in the distribution of plant species in hedgerows (Deckers *et al.* 2004). Soil is one of the several environmental factors controlling the distribution of vegetation types and can be the most important under some conditions. It is the medium of growth of land plants and provider of physical support, moisture and nutrients (Fisher and Binkley 2000).

Plant distributions are governed by a combination of broad scale bioclimatic and historic factors as well as the local conditions at a particular site (Barbour *et al.* 1987). Over a small range however species distribution is related to edaphic factors (Ayyad and Ghareeb 1972).

The distribution and ecological properties of *H. rhamnoides* have been investigated in many studies. The habitat occupied by seabuckthorn is diverse and include sand dunes, tidal estuaries and riverbank. It is one of the invasive plants in the coastal dune system. During succession, it rapidly spreads through the dunes to form large monotypic stands. However, in a course of time, the rate of spread declines due to increased competition with grass and in reduction in areas of bare sand. Wherever there is an ample supply of propagules, seabuckthorn stand are replaced by a number of shrubs and tree species (Binggeli 1992). *Hippophae rhamnoides* represents the shrubland stage during the successional stage in the abandoned croplands in Loess Plateau (Zhang 2005). On the contrary, the two species of seabuckthorn in Nepal, *H. salicifolia* and *H. tibetana* have been left in a black box. The geographical distribution, natural habitat, ecological niche etc. of these species should be clarified for proper utilization and plantation of seabuckthorn in Nepal

1.4 Objectives

This study aims to achieve the following objectives:

- To explore the distribution of seabuckthorn in Nepal
- To determine the habitat of seabuckthorn

2. Study area

The area of present study lies on Northwest Nepal. Four districts of Karnali zone, viz.: Jumla, Humla, Mugu, Dolpa, one district of Dhaulagiri zone - Mustang and one district of Gandaki zone - Manang are the representative districts worked out for seabuckthorn resource in the Himalayas. The total study sites cover an area of 25429 km² which comes to about 17 % of the total area of Nepal, extending in between 81° 12'E to 84° 34'E and 28° 27'N to 30° 17'N. The altitudinal range varies from 915 m (Jumla) to 8167 m (Mt. Dhaulagiri). Extending east to west, from Mt. Manasalu to Mt. Saipal, extensive areas of arid mountain slopes here are covered by xerophytic arboriform species, particularly the foot hills of the eastern end of the Northwest Himalayas and often extending deep into the Sulej valley. The area is surrounded by the Tibetan plateau to the north. Due to the variation in altitude, it represents the subtropical (1000- 2000 m a.s.l), temperate (2000- 3000 m a.s.l) and alpine (above 3000 m a.s.l) type of physiographic regions. It has diverse type of flora and fauna which is an important sight for the biologist and naturalist as well. Besides this, it is also a centre for tourism industry. The largest and beautiful lake Rara (Mugu), deepest lake Phoksundo (Dolpa), lake in the highest elevation, Tilicho (Manang), Shey Phoksundo national park, Annapurna Conservation Area Project (ACAP), water falls, hot springs, Monasteries, Himalayan peaks etc are the places for natural attractions. Holy places such as Damodar Kunda, Muktinath, and Shey-gompa are famous among Hindu and Buddhist.

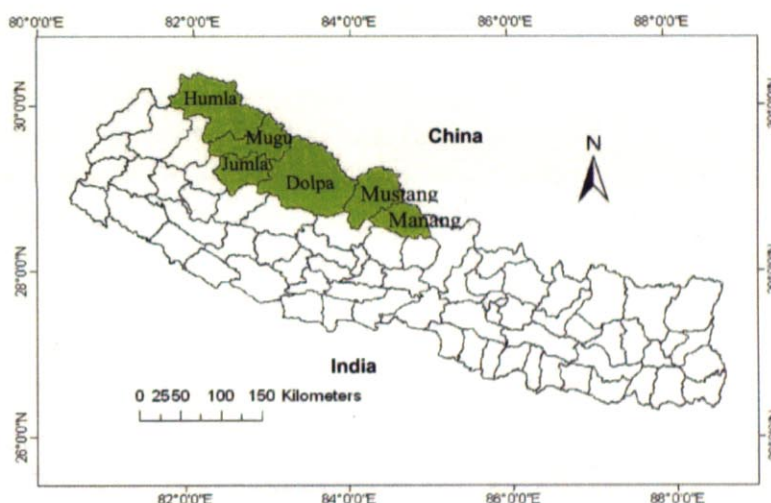


Fig. 3: Study area

Mustang district covers an area of 3573 km² and lies at 28°24' to 29°20'N latitude and 83°30' to 84°10'E longitude. The altitude varies from 1372 m to 8167m. Northern part of the district is surrounded by Tibetan Plateau. It is cold high altitude steppe, caught in the rain shadow of the mount Dhaulagiri to west and Annapurna massif to the east. The entire district lies within the Annapurna Conservation Area, the largest protected area of Nepal. Kaligandaki which originates as mustang khola in the north and flows due south creating the deepest gorge in the world between the Mt. Dhaulagiri (8167masl) and Mt. Annapurna (8091masl) is the major river system in the district.

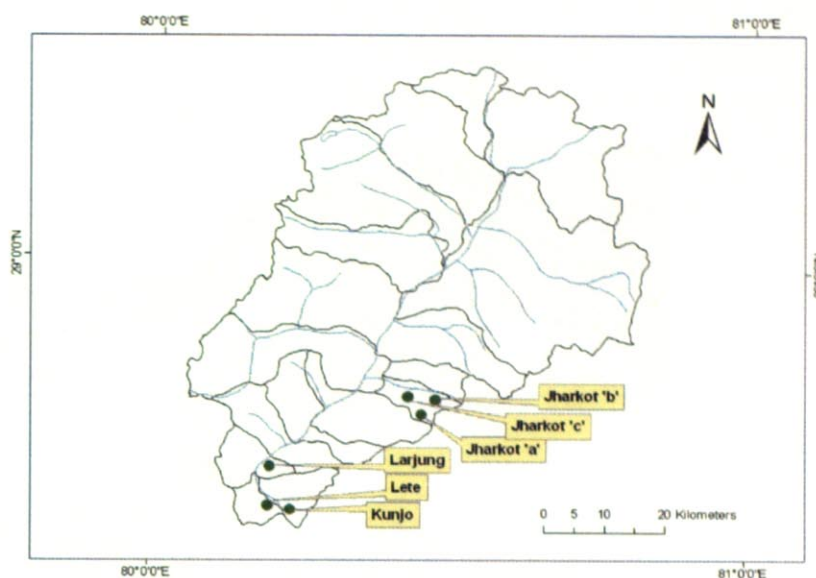


Fig. 4: Location of studied sites in Mustang district

There are two distinct seasons: April to October is mild when all agricultural activities are carried out and November to March is severe and precipitation invariably is in the form of snow. Strong wind and high solar radiation characterize the region most of the year.

Lete, Kunjo, Larjung and Jharkot were the studied sites in this research. Lete, Kunjo and Larjung are located in a small valley made by Kaligandaki River. *H. salicifolia* were well distributed on these areas. Jharkot represents the high altitude grasslands dominated by dry alpine scrub where *H. tibetana* was studied.

The climatic data of nearer weather station is illustrated in the Fig. 5. There was record of temperature, humidity and rainfall data in Lete (latitude $28^{\circ} 38'$ and longitude $83^{\circ} 36'$; altitude 2384 m) and rainfall in Ranipauwa (latitude $28^{\circ} 49'$ and longitude $83^{\circ} 53'$; altitude 3609 m). Lete represents the climatic condition of *H. salicifolia* sites and Ranipauwa represents the rainfall condition of *H. tibetana* site.

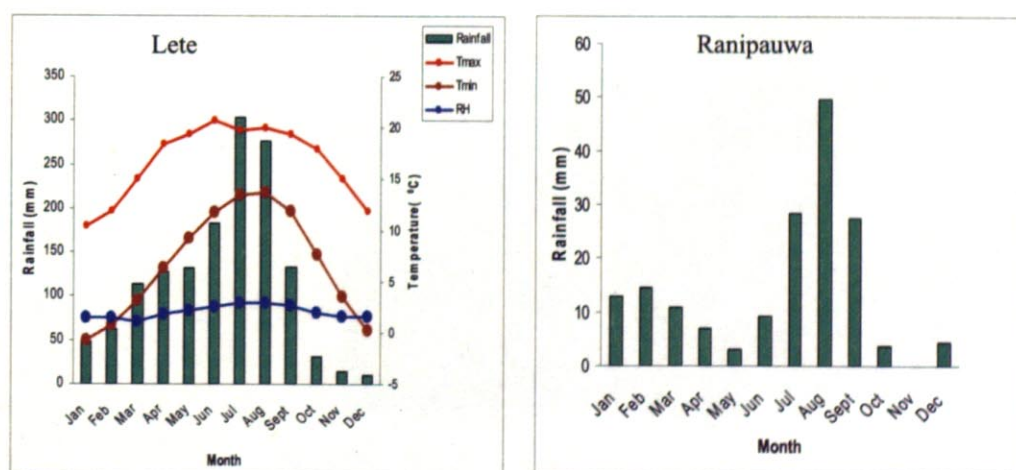


Fig. 5: Climatic condition of studied area.

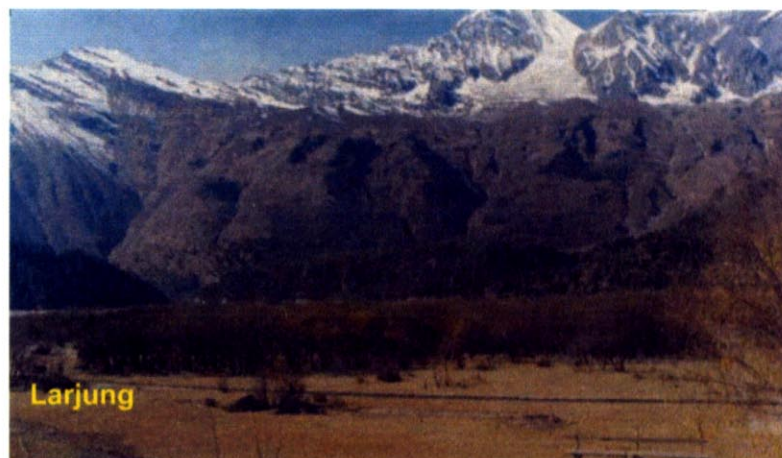


Fig.6: Representative pictures of each studied site in Mustang

2.1 Vegetation:

Mustang district is geographically divided into two sectors: lower and upper Mustang. Lower Mustang receives more precipitation and coniferous forest grows in that area. Tree species occurred in the forest are *Pinus wallichiana*, *Picea smithiana*, *Taxus baccata*, *Cupressus torulosa*, *Abies spectabilis*, etc. The other tree species of this area include *Alnus nepalensis*, *Betula alnoides*, *Betula utilis*, *Mallotus nepalensis*, *Hippophae salicifolia*, *Rhododendron arboreum*, etc.

The natural vegetation of the upper Mustang is mainly dry alpine scrub frequented by Tibetan plant species. However, few patches of forest composed of mainly *Juniperus squamata*, *Betula alnoides* and *Populus ciliata* are found in some places. The other dominant flora of this region is *Hippophae tibetana*, *Rhododendron lepidotum*, *Lonicera obovata*, *Spiraea arcuata*, etc. All high altitudes pastures above 4000 m consist of alpine meadows.

This district is rich in rare and endangered species that have been used medicinally for centuries by traditional Tibetan doctors. It is also a home to many endemic species of plants (*Poa mustangensis*, *Clematis bractolata*, *Saxifraga neopropagulifera*), although the exact number of species is currently unknown.

2.2 Botanical works in Mustang

Some expeditions were made to explore the vegetation of Mustang district (Stainton 1972). The expeditions of Japanese botanists have contributed in the botanical knowledge of the district (Noshiro and Rajbhandari 2002). Tsukaya et al. (2005) collected three hundred and fifty five plant specimens along with the corresponding DNA samples from upper Mustang. The activities of Annapurna Conservation Area Project (ACAP) and International Centre of Integrated Mountain Development (ICIMOD) mainly focused on the rangeland management on the upper Mustang region. Some works were focused on the collection of plant specimens (Shrestha 1984), vegetation types (Koirala and Shrestha 1997), floral ecology (Shrestha 2004), Non-timber forest product (Kshetri 2004) and ethno- medico botanical survey (Subedi 2004) in the district. Nepal *et al.* (2000) explore the seabuckthorn resources in the district and Subedi and Adhikari (2001) worked on the propagation techniques of the same.

3. Materials and method

This study was conducted in two phases. In the first phase, general distribution pattern of seabuckthorn in the six northwest districts of Nepal was surveyed and in the second phase vegetation and soil survey of *Hippophae* stands in Mustang district was done.

3.1 Plant species

Hippophae salicifolia and *H. tibetana* were two species studied in this research. *H. salicifolia* is commonly known as 'Dale Chuk' or 'Chichi' and *H. tibetana* as 'Tora' in Nepal.

H. salicifolia D. Don is a tree or bush (usually 2-4 m), with long, slender, willow-like branches and few thorns. Leaves alternate, 55-85 mm long, 9-11 mm broad, broadest about the middle, slightly folded longitudinally; margins revolute, base cuneate, apex acute, 15-30 vein pairs; upper surface green, lower surface tomentose, dull grey, usually with a prominent rust colored midrib; petiole usually 2-3mm. Female flower containing one ovary with one anatropous ovule. Tapels of the male flower 3-4 mm long, obtuse. Fruits orange yellow to pale greenish-brown; seeds flat, with a furrowed surface and a parchment- like hull that is difficult to remove, 3.1- 5.2 mm long, 1.9- 3.1 mm broad, 1- 1.9 mm thick.



Fig. 7: *Hippophae salicifolia*

H. tibetana Schlecht is a bush, 10-80 cm high with a thick tortuous, knobby stem and abundant upright shoots ending in thorns. Leaves normally 3 in a whorl, 8-20 mm long, 2-4 mm broad, broadest about the middle, not folded, margin flat, base cuneate, apex more or less obtuse, ca. 8-11 vein pairs, upper surface green to silvery; lower surface covered with peltate hairs, silvery or rust colored, not tomentose; petiole not more than 1 mm long. Tepals of the male flower ca. 3

mm long, apiculate. Fruits orange red; seeds 4-5.6 mm long, 1.9- 2.8 mm broad, 1.3-2.3 mm thick, somewhat flattened.



Fig. 8: *Hippophae tibetana*

3.2 Field methods

To study the distribution pattern, seabuckthorn habitat in each district were visited based on the information provided by the local people. Altitude, aspect, slope, longitude and latitude of each place were noted. Quadrat of size 10 m \times 10 m for *H. salicifolia* and 5 m \times 5 m for *H. tibetana* were laid down in their respective sites. Number of mature trees, seedlings and saplings were counted to know the regeneration status in each site. Number of cut stumps was counted in the investigated plots to know the utilization of plant for timber and firewood. Cattle droppings were noted and some cattle herders were interviewed about the frequency of cattle on the forest. Associated species in each site was recorded.

To determine the soil factor for seabuckthorn distribution, field survey was conducted in the Mustang district during August 2006. The study included 9 plots in 3 sites for each species of *Hippophae*. Transect of 100 m long was laid down along the slope in each site. Three plots were set along transect in such a way that Plot 1 was located near the river bank/water source, Plot 2 on the middle slope and Plot 3 on the upper slope. The plots were selected purposively so that Plot 1 and Plot 2 had abundant seabuckthorn while Plot 3 lacked in it. The size of plot was 10m \times 10m and 5m \times 5m for *H. salicifolia* and *H. tibetana*, respectively.

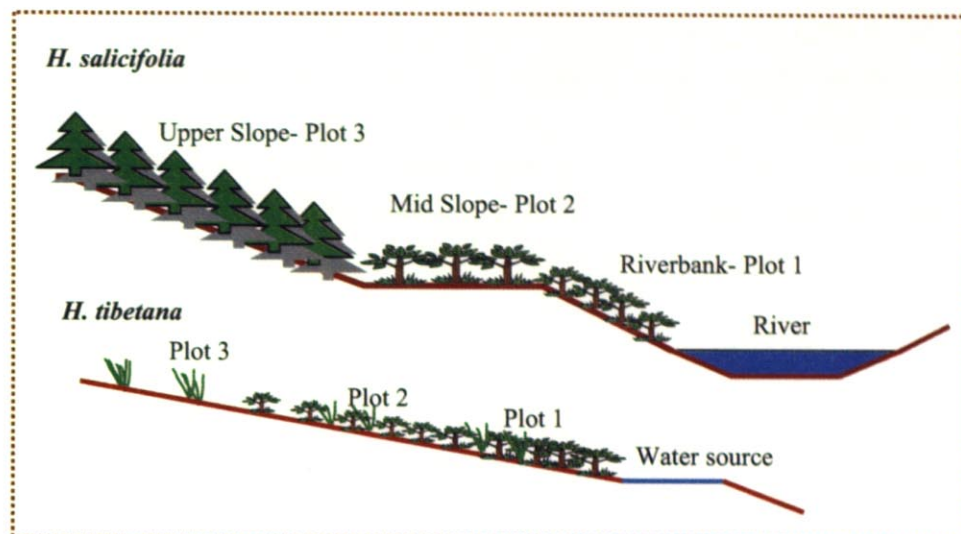


Fig. 9: Lay out of plots along the transects

Information of each plot such as slope, aspect, altitude, longitude, and latitude was recorded (Table 1). Slope and altitude was measured using clinometers and altimeter respectively. Aspect was measured using altimeter and the longitude and latitude of each plot was taken using a portable GPS receiver (eTrex Vista, Garmin).

Table1: Site characteristics/ Plot details

Site	Plot	Plot size	Altitude (m)	Aspect	Slope ($^{\circ}$)	GPS reading ($^{\circ}$)		Species
						N	E	
Kunjo	1	10 m \times 10 m	2340	SE	55	28.633930	83.616470	<i>H. salicifolia</i>
	2	10 m \times 10 m	2392	SE	0	28.634250	83.616790	
	3	10 m \times 10 m	2407	SE	20	28.634610	83.617230	
Lete	1	10 m \times 10 m	2405	NE	15	28.633833	83.617778	
	2	10 m \times 10 m	2438	NE	45	28.633611	83.617889	
	3	10 m \times 10 m	2451	NE	60	28.633361	83.617444	
Larjung	1	10 m \times 10 m	2538	NW	0	28.678667	83.619000	
	2	10 m \times 10 m	2539	NW	5	28.678472	83.619500	
	3	10 m \times 10 m	2538	NW	0	28.678389	83.619917	
Jharkot 'a'	1	5 m \times 5 m	3612	NW	26	28.811500	83.851740	<i>H. tibetana</i>
	2	5 m \times 5 m	3616	NW	17	28.811320	83.851900	
	3	5 m \times 5 m	3630	NW	19	28.810930	83.852390	
Jharkot 'b'	1	5 m \times 5 m	3599	NW	22	28.811111	83.853806	
	2	5 m \times 5 m	3607	NW	30	28.810750	83.853944	
	3	5 m \times 5 m	3618	NW	12	28.810333	83.854028	
Jharkot 'c'	1	5 m \times 5 m	3566	NW	12	28.815250	83.854028	
	2	5 m \times 5 m	3568	NW	10	28.815194	83.854583	
	3	5 m \times 5 m	3569	NW	30	28.815056	83.855000	

3.3 Vegetation survey

Height and diameter at breast height (DBH) at 1.3 m above the ground of the tree were measured to determine basal area, DBH class distribution and height class distribution in the *H. salicifolia* site. Diameter at the ground level and height were measured for the shrubs. The herbs were measured by recording maximum height of each species and their coverage. The position of tree and shrubs in each plot was recorded. Unidentified plants were identified in National Herbarium and Plant Laboratory, Kathmandu, Nepal.

3.4 Soil sampling

Soil sample was collected from five places of each investigated plot and average value was calculated to represent the plot. Surface soil of 0- 5 cm depth was taken from each place. Stones, twigs, leaves were removed from the soil. About 300 g of soil was packed in a sampling bag and carried to Kathmandu for analysis. Eighty g of soil from each packet was brought to Japan for analysis.

3.5 Vegetation analysis

Shannon- Weiner Index (H'), dominance (D) and evenness (E) were used to measure the species diversity of ground vegetation in each plot. Formula used to measure each index was;

$$\text{Diversity } (H') = - \sum_{i=1}^S p_i \ln_2 p_i$$

$$\text{Dominance } (D) = \sum p_i^2$$

$$\text{Evenness } (E) = [1/D]/s$$

Where,

s = number of species

p_i = proportion of species

All the vascular plant species recorded in the plots was arranged according to Raunkaier's (1934) system and disseminule form (Numata *et al.* 1990). Raunkaier's life form was based on the position of perennating organs in relation to soil surface and plants were arranged into five major classes: phanerophytes, chamaephytes, hemicryptophytes, cryptophytes and therophytes. The diiseminule form is based on the development of seed dispersal mechanism in plants.

The abbreviations used in the text are as follows: Ph, Phanerophyte; Na, Nanophanerophyte; Ch, Chamaephyte; He, Hemicryptophyte; Th, Therophyte. D1, Disseminated widely by wind and water; D2, Disseminated attaching with or eaten by animals and man; D3, Dissiminated by mechanical proulsion of dehiscence of fruits; D4, Having no special modification for dissemination; D5, Not producing seeds.

3.6 Soil analysis

The physical and chemical characteristics of soil were analyzed in Nepal and Japan. Soil characteristics such as texture, pH, electrical conductivity, phosphorus and potassium were analyzed in soil science division, National Agricultural Research Council (NARC), Kathmandu. Soil pH was determined by making 1:2 soil water suspensions with the help of pH meter using calomel electrode assembly. Soil texture was determined by hydrometer method. 1:2 soil water suspensions was made and kept for whole night to measure electric conductivity by electrometer. The available phosphorus and potassium was determined by trougs and flame photometer respectively.

Carbon and nitrogen was analyzed in the laboratory of evaluation of natural environment, University of Tokyo by NC analyzer (Thermo Finnigan Eager 300). For the analysis, air dried (at room temperature) soil was grinded by ceramic grinder and passed through 250 μm sieve. Based on the percentage of organic matter 5 mg (more organic matter) and 20- 25 mg (less organic matter) of soil was taken for the analysis. The weighted soil was put into Universal tin container (Thermo Quest Italia S.p.A), packed and passed to the analyzer. Aspartic Acid ($\text{C}_4\text{H}_7\text{NO}_4$) Standard (Thermo Quest Italia S.p.A) was used for calibration of methods and control of the analysis.

3.7. Statistical analysis

The data obtained from the analysis of soil were not distributed normally. Thus, non-parametric test (Kruskal- Wallis) was used to analyze the data by using software JMP.

4. Results

4.1 Distribution of seabuckthorn in northwest Nepal

During the survey period two species of *Hippophae*, *H. salicifolia* and *H. tibetana* were recorded from northwest Nepal (Fig. 10). Out of six districts, *H. tibetana* was not recorded from Mugu and Jumla.

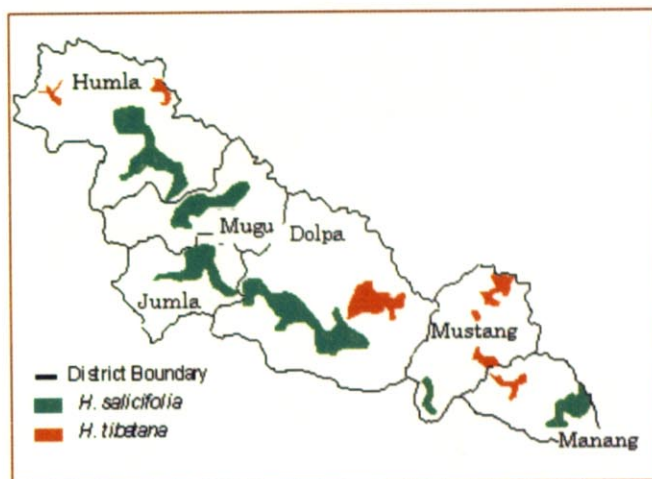


Fig. 10: Distribution of seabuckthorn in northwest Nepal

H. salicifolia occurred on the fragile lands with weak soil composition and unfertile river fords, southwest facing slope and plain land in all the surveyed districts. It was also found in the mountain slope and gullies except Mustang and Manang district where it mostly confined in the riverbank. *H. tibetana* was found on plain land near water bodies in all the districts.

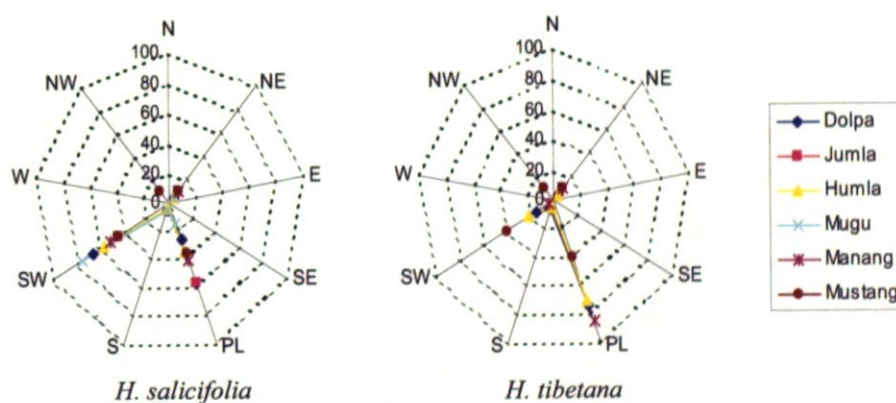


Fig. 11: Slopewise occurrence of seabuckthorn in different districts
N, North; NE, Northeast; E, East; SE, Southeast; PL, Plain land; S, South; SW, Southwest; W, West and NW, Northwest

It was noticed in the field that *H. salicifolia* occurred between the altitudes 2000 – 3800 m. Likewise *H. tibetana* was found occurring between 2900- 4500 m (Fig. 12). The lower altitudinal boundary for the distribution of *H. salicifolia* was 2000 m in the Mustang district and higher was 3850 in the Dolpa district. Similarly, the lower boundary for the occurrence of *H. tibetana* was 2900 m in Mustang and upper was 4500 m in Dolpa district. It was noteworthy that the far western districts have, in general, availability of species with increased altitude and corresponding to decrease longitude.

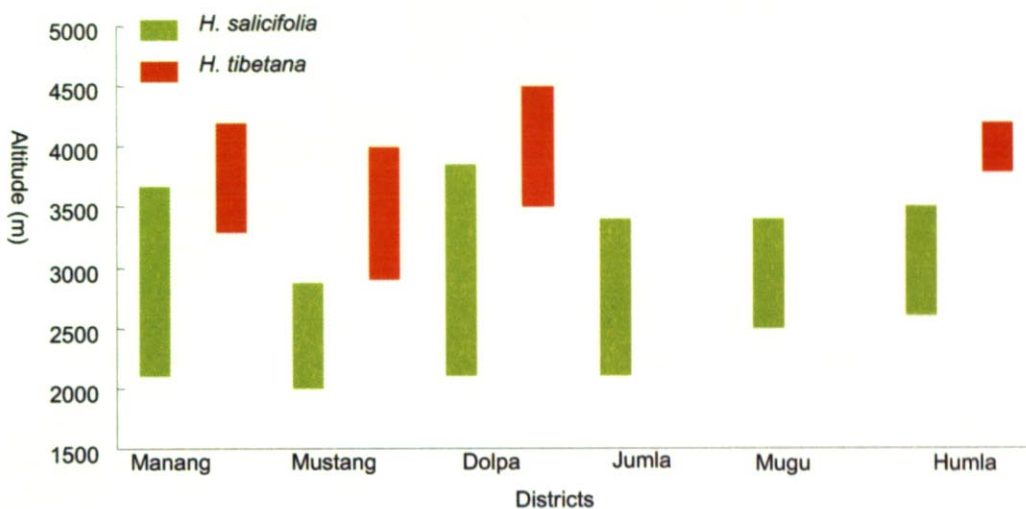


Fig. 12: Altitude wise distribution of seabuckthorn in different districts

Different plants were recorded from various surveyed sites as the associated species of *Hippophae*. Among them, few plants with high frequency are illustrated in the Table 2 and 3. Some plants were common among different districts. *Pinus wallichiana* and *Caragana brevispina* were more frequent plant in *H. salicifolia* and *H. tibetana* sites respectively.

The major associates of *H. salicifolia* in Manang and Mustang districts were *Alnus nepalensis*, *Pinus wallichiana* and *Arundinaria falcata* in the lower elevations and *Pinus wallichiana*, *Ephedra gerardiana*, *Tsuga dumosa*, *Betula utilis* and *Daphne bholua* in the higher elevation. It chiefly occurred with *Desmodium elegans*, *Rosa* sp. and *Prinsepia utilis* in Dolpa and Jumla district and *Pinus wallichiana* and *Prinsepia utilis* in Mugu and Humla district.

Caragana brevispina, *Ephedra gerardiana*, *Juniperus communis*, *Lonicera angustifolia*, *Myricaria germanica* were common associates of *H. tibetana* in Mustang and Manang district. Similarly, *Astragalus candolleanus*, *Caragana brevispina* and *Myricaria rosea* were in Humla and Dolpa district.

Table 2: Major woody associates of *H. salicifolia* in NW Nepal

Species	Habit	Districts					
		Mustang	Manang	Humla	Mugu	Dolpa	Jumla
<i>Alnus nepalensis</i>	Tree	+					
<i>Coriaria nepalensis</i>	Tree		+				+
<i>Juniperus</i> sp.	Tree	+					
<i>Picea smithiana</i>	Tree		+				
<i>Pinus wallichiana</i>	Tree	+	+	+	+		+
<i>Populus ciliata</i>	Tree					+	
<i>Populus</i> sp.	Tree		+				
<i>Quercus semecarpifolia</i>	Tree					+	
<i>Salix</i> sp.	Tree		+			+	
<i>Arundinaria falcata</i>	Shrub	+	+				
<i>Berberis asiatica</i>	Shrub			+		+	
<i>Berberis erythroclada</i>	Shrub	+	+				
<i>Colquhounia coccinea</i>	Shrub						
<i>Cotoneaster frigidus</i>	Shrub					+	+
<i>Daphne bholua</i>	Shrub		+				
<i>Desmodium elegans</i>	Shrub			+		+	
<i>Ephedra gerardiana</i>	Shrub	+					
<i>Prinsepia utilis</i>	Shrub			+	+	+	+
<i>Rosa sericea</i>	Shrub			+			
<i>Rosa</i> sp.	Shrub		+			+	
<i>Salix tibetana</i>	Shrub	+					
<i>Sophora</i> sp.	Shrub	+					+
<i>Spiraea arcuata</i>	Shrub					+	

Table 3: Major woody associates of *H. tibetana* in NW Nepal

Species	Habit	Districts			
		Mustang	Manang	Humla	Dolpa
<i>Astragalus candolleanus</i>	Shrub			+	+
<i>Berberis erythrocladum</i>	Shrub	+			
<i>Caragana brevispina</i>	Shrub	+	+	+	+
<i>Cotoneaster</i> sp.	Shrub		+		
<i>Ephedra gerardiana</i>	Shrub	+	+		
<i>Juniperus communis</i>	Shrub	+	+		
<i>Juniperus indica</i>	Shrub				+
<i>Lonicera angustifolia</i>	Shrub	+	+		
<i>Lonicera webbiana</i>	Shrub				+
<i>Myricaria germanica</i>	Shrub	+	+	+	
<i>Myricaria rosea</i>	Shrub			+	+
<i>populus tibetana</i>	Shrub	+			
<i>Rosa erythroclada</i>	Shrub	+			
<i>Rosa sericea</i>	Shrub		+		+
<i>Rosa</i> sp.	Shrub	+			
<i>Salix calyculata</i>	Shrub		+		

4.2 Topographical habitat of seabuckthorn in Mustang district

4.2.1 Species and life-form spectrum

A total of 55 species representing 51 genera and 27 families were identified in the *H. salicifolia* studied sites (Annex 1). Herbaceous species were dominant representing 65% of total vegetation and 25% were perennial. Asteraceae (10 species), Rosaceae (7 species) and Ranunculaceae (4 species) representing 17.8%, 12.5% and 7.14% of the total flora respectively were the largest families.

There were a total of 44 species belonging to 38 genera and 21 families in *H. tibetana* sites (Annex 2). Annual herbaceous species dominated (61.36%) followed by perennial shrubs (25%) and graminoid species (11.3%). The largest families were Asteraceae 20.45%, Ranunculaceae 9.09% and Rosaceae 9.09% of the total flora recorded during investigation.

The Raunkiaer's life form of vascular plants of each site is illustrated in the Fig. 13. There was no consistency in the occurrence of different life form among the sites of *H. salicifolia*. The floral life form in all plots of Kunjo was dominated by therophytes; 54.5 % in plot 1, 69.2 % in Plot 2 and 41.1 % in plot 3. Similarly, Larjung had higher percentage of therophytes in each plot. The order of occurrence of therophytes in Larjung was Plot 1 > Plot 2 > Plot 3. Plot 1 and Plot 3 in Lete had the highest percentage of hemicryptophytes than other life form. The percentage of nanophytes was the highest in Plot 2.

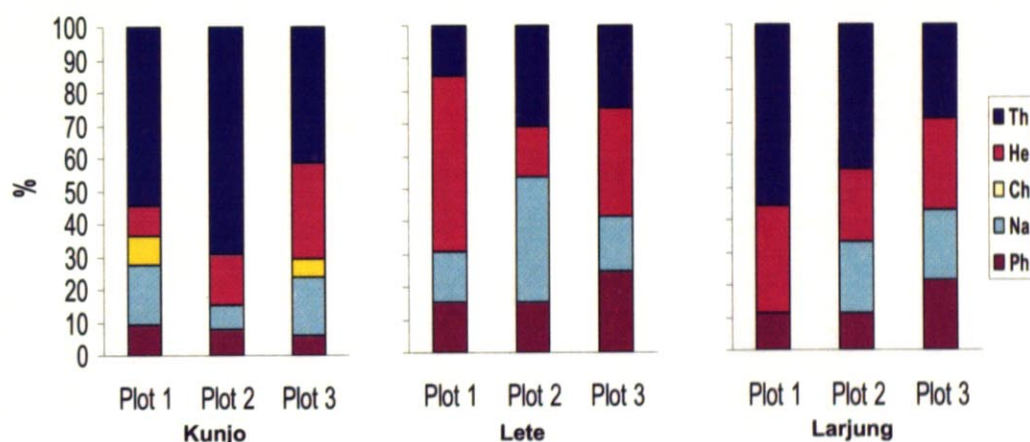


Fig. 13: The spectra of Raunkiaer life form in *H. salicifolia* sites.

Where, Ph, Phanerophyte; Na, Nanophanerophyte; Ch, Chamaephyte;

He, Hemicryptophyte; and Th, Therophyte

Based on the disseminule form, the majority of plants (more than 50 %) in all the sites belonged to group D₄ (Fig. 14). Plants under the disseminule group D₂ were not found in Plot 2 of Lete and Plot 1 of Larjung.

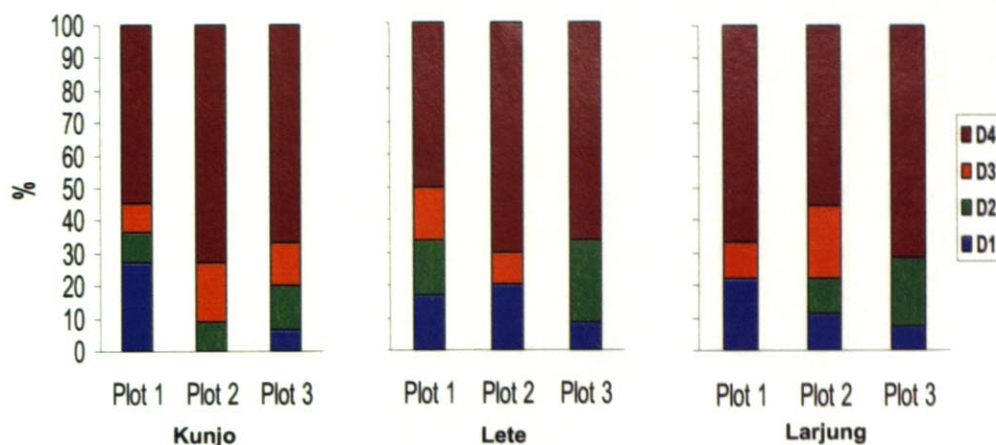


Fig. 14: The spectra of disseminule forms in *H. salicifolia* sites

Where, D1, Disseminated widely by wind and water; D2, Disseminated attaching with or eaten by animals and man; D3, Dissiminated by mechanical proulsion of dehiscence of fruits; D4, Having no special modification for dissemination; D5, Not producing seeds

Therophytes, hemicryptophytes and nanophytes were the floristic life form recorded in the *H. tibetana* studied sites (Fig. 15). The highest percentage of life form were hemicryptophytes in all Seabuckthorn occurring plots as compared to plots without them except at Jharkot 'b' where, Plot 3 contained high percentages of hemicryptophytes than Plot 1 and Plot 2. The percentage of nanophytes was in the order Plot 1 < Plot 2 < Plot 3 in sites Jharkot 'a' and Jharkot 'c' while the trend was opposite in Jharkot 'b'.

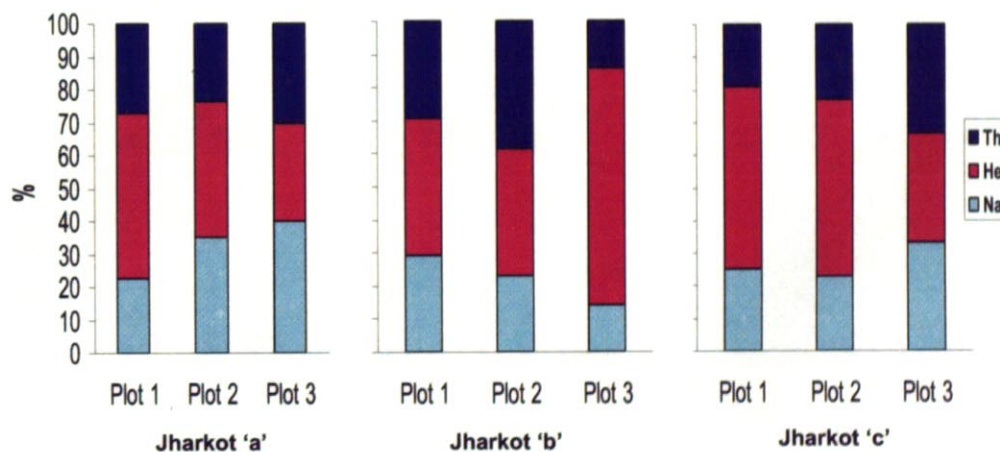


Fig. 15: The spectra of Raunkiaer life form in *H. tibetana* sites

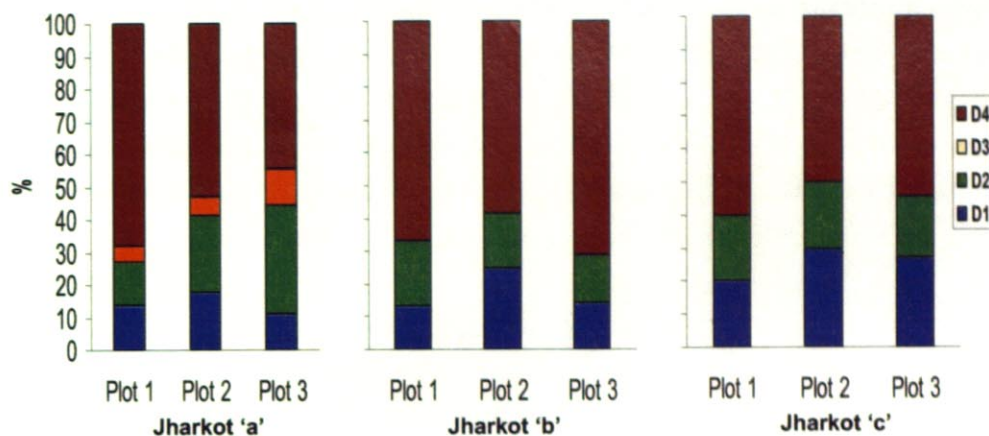


Fig. 16: The spectra of disseminule forms in *H. tibetana* sites

D₁, D₂, D₄ were the major disseminule form of plants recorded in Jharkot (Fig. 16). However, D₃ form was also recorded in Jharkot 'a'. D₄ was the dominated disseminule form in Jharkot.

4.2.2 Size distribution

H. salicifolia were grouped into size class according to DBH (in 5 cm diameter interval) (Fig. 17) and height (with the interval of 2 m) (Fig. 18). DBH of *H. salicifolia* varied from 2.9 cm to 25.5 cm in all sites.

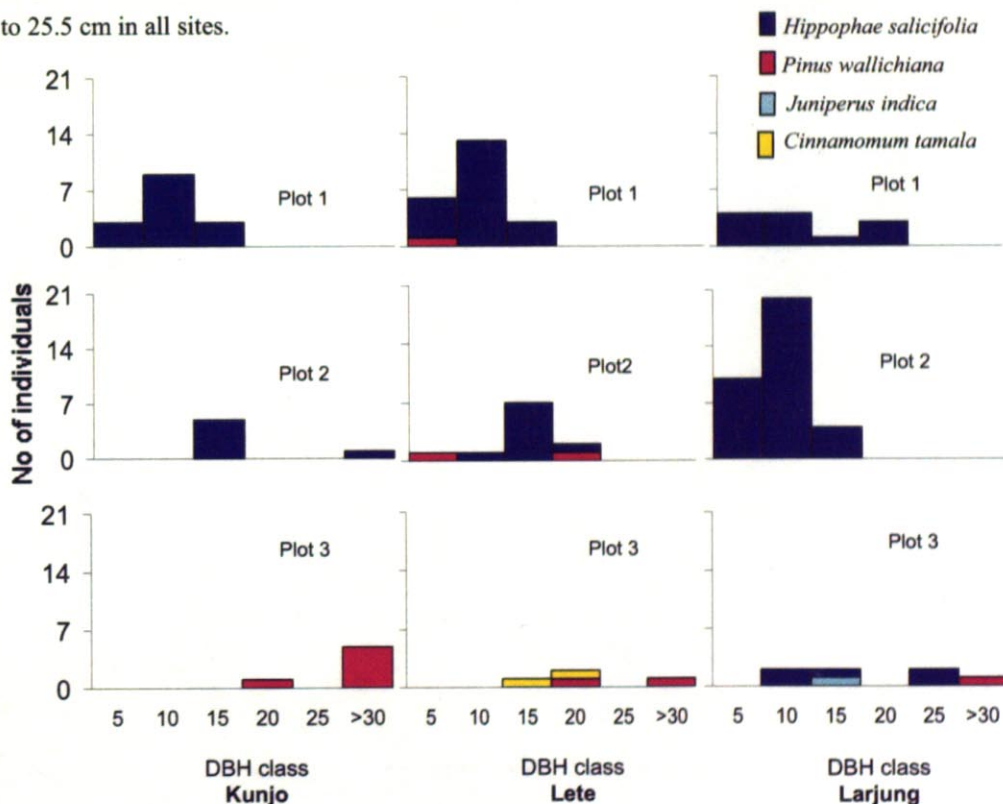


Fig. 17: DBH -class distribution of tree in *H. salicifolia* sites

The number of *H. salicifolia* was high in Plot 1 at Kungo and Lete. While the number was high in Plot 2 at Larjung. A large number of Seabuckthorn in Plot 1 of Kunjo and Lete were on the DBH class 10cm, while the class was 15 cm in Plot 2 of each sites. Contrary to other sites, DBH class was reported high in Plot 1 than Pplot 2 at Larjung. Plot 1 and 2 were the monodominant stand of *H. salicifolia* in all the sites except Lete where two individuals of *Pinus wallichiana* were found in Plot 1 and one individual in Plot 2. Few individuals of Seabuckthorn were found in Plot 3 of Larjung.

Plot 2 at each site had high height class individuals of seabuckthorn than Plot 1 However in Lete, large number of individuals were 8 m height class in both the plots. The 2 m height class individuals were absent in Plot 2 of Kunjo and Lete but were present in Larjung.

The three plots of each transect showed the successional trend in river banks: young individuals of *H. salicifolia* were distributed in the lowest Plot 1, mature individuals of *H. salicifolia* and seedlings of *Pinus wallichiana* in middle slope Plot 2, then *Pinus wallichiana* forest without *H. salicifolia* at Plot 3.

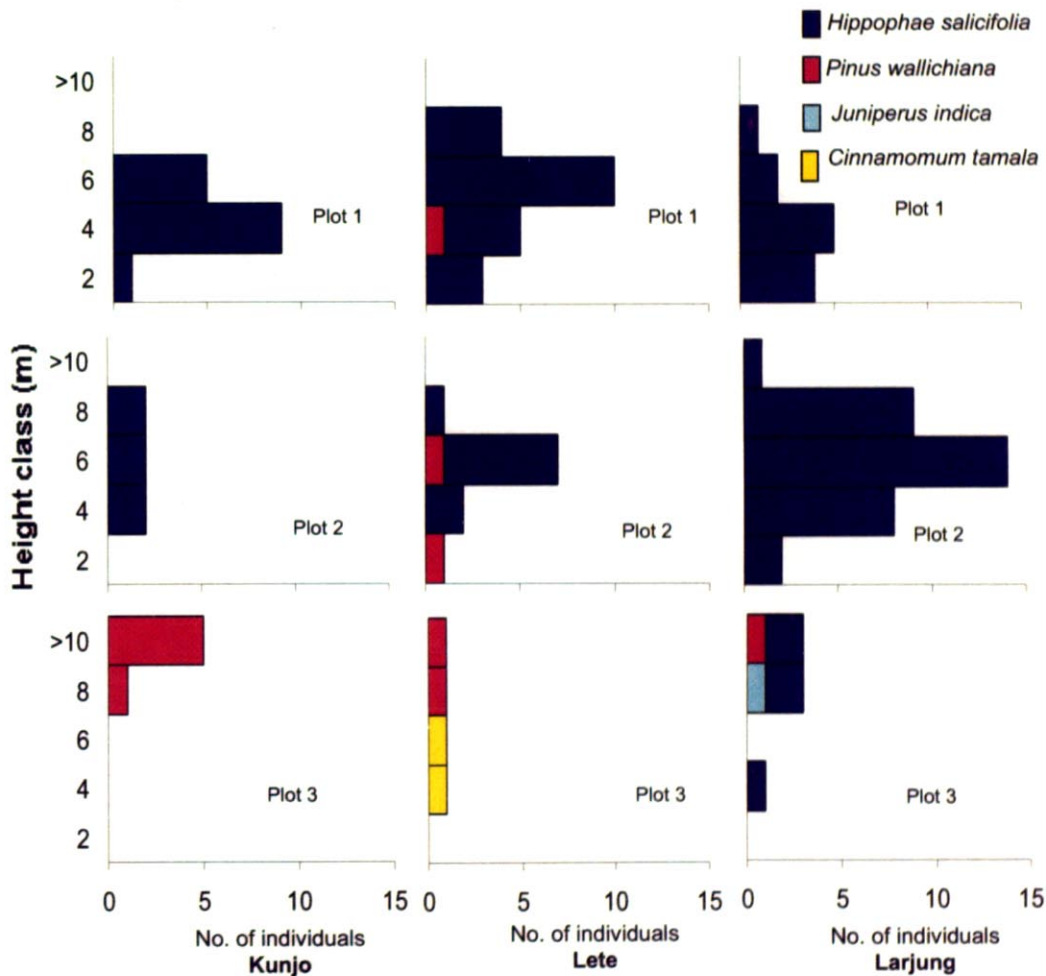


Fig. 18: Height -class distribution of tree in *H. salicifolia* sites

The diameter at the ground level (D_0) of *H. tibetana* were grouped at an interval of 0.5 cm (Fig. 19). It revealed that the Plot 1 in all sites was occupied by high D_0 class individuals of seabuckthorn than Plot 2. DBH class of *H. tibetana* was high as compared with associated shrubs in Plot 1 of all the sites. The DBH class of associated species was high in Plot 2 of the sites Jharkot 'b' and Jharkot 'c'.

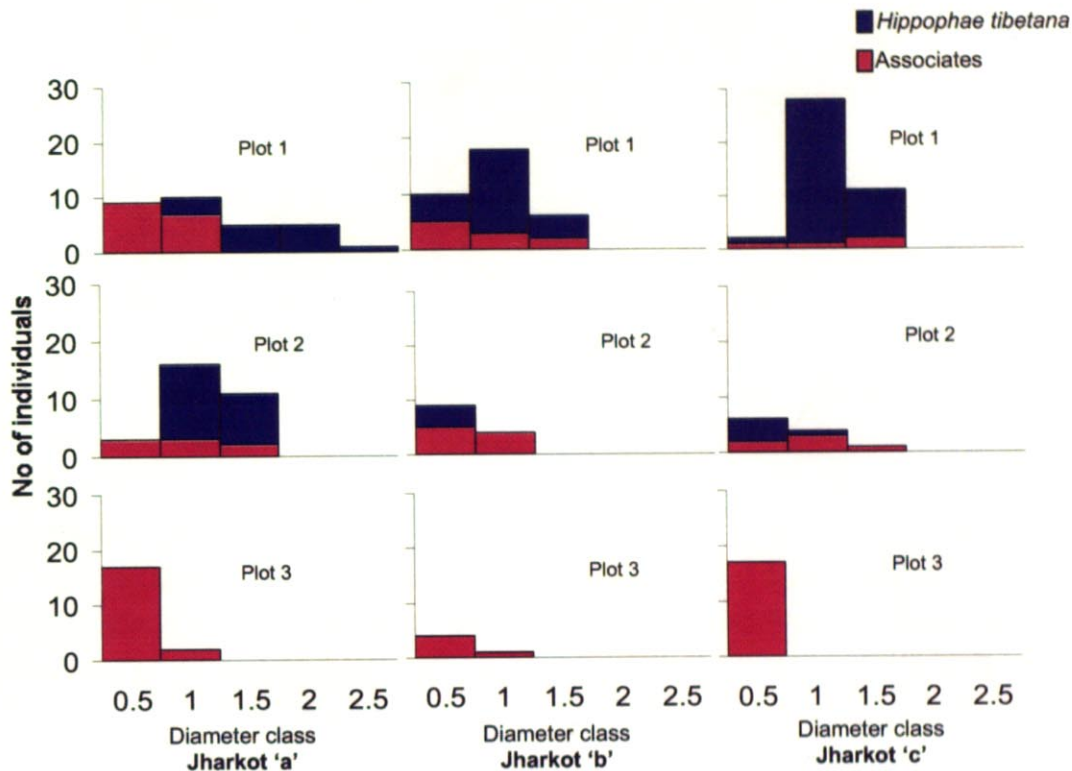


Fig. 19: Diameter (D_0) -class distribution of shrubs in *H. tibetana* sites

The height class of *H. tibetana* was taken at the intervals of 0.25 m (Fig. 20). The height class was not distributed uniformly in different plots. Large no of *H. tibetana* recorded in Jharkot 'a' were under .75 m and 1 m class in both Plots 1 and 2. In Jharkot 'b' all individuals grouped under .25 and .50 m class and in Jharkot 'c', the height class of all individuals of *Hippophae* in Plot 1 was higher than that of Plot 2. Therefore, *H. tibetana* occupies the lowest part of the slope as a late successional species of the alpine rangeland.

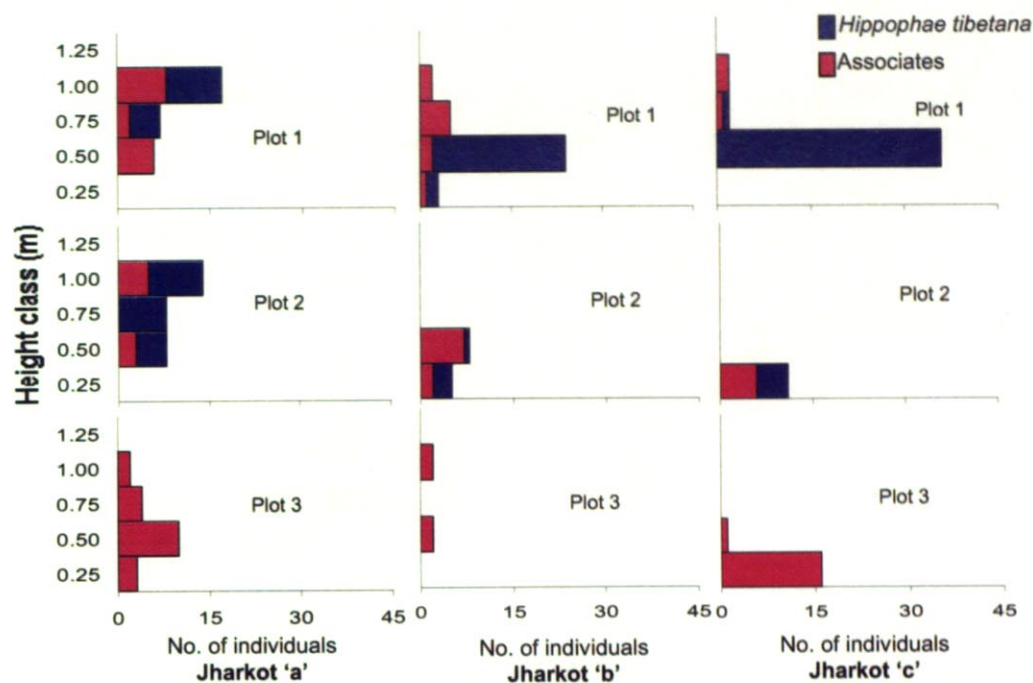


Fig. 20: Height -class distribution of shrubs in *H. tibetana* sites

4.2.3 Height- diameter relationship

The height – diameter relationship of seabuckthorn in different plot is illustrated in the Fig. 21. The allometric growth model with power function type regression explained the high percentage of variation (ecologically sound) in majority of plots. The variation was not explained well in plot 2 of Lete and larjung and seabuckthorn occurring plot of Jharkot 'a'.

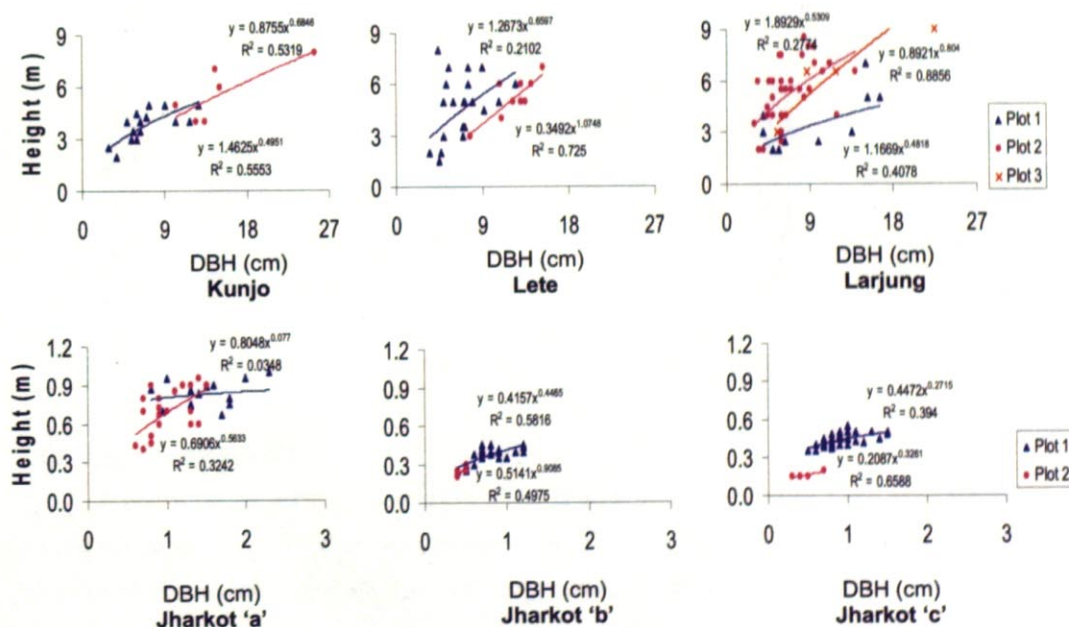


Fig. 21: Height- diameter relationship

4.2.4 Basal area

There was gradual increase in the basal area of tree species along the slope from river bank plot to upper slope plot (Fig. 22). Since the Plot 3 of Kunjo and Lete had large sized pine, it was obvious to note that the basal area was much higher than other *Hippophae* growing plots. However, the differences in basal area among the plots in Larjung were not so high as compared to other sites.

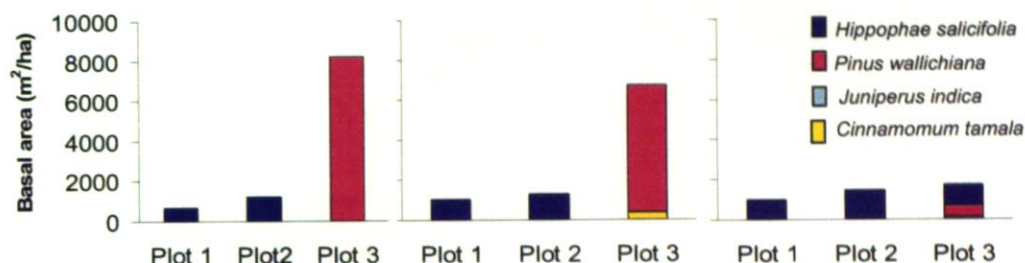


Fig. 22: Basal area of tree in *H. salicifolia* sites

The basal area (D_0) of different shrubs in *H. tibetana* sites is shown in the Fig. 23. There was gradual decrease in the basal area of *Hippophae* from Plot 1 to Plot 2. In all the sites, Plot 1 represented higher basal area than that of other plots. However, Plot 2 in Jharkot 'a' had high basal area than other shrubs. Contrary with *H. salicifolia* sites, Plot 3 in Jharkot had scarce vegetation that resulted in low basal area.

Thus, the successional trend in *H. tibetana* sites is opposite to *H. salicifolia* site, namely, Plot 1 is the most developed stand and Plot 3 is the earliest pioneer stage. *H. tibetana* is a late successional shrub here with *Juniperus squamata* and *Lonicera* spp.

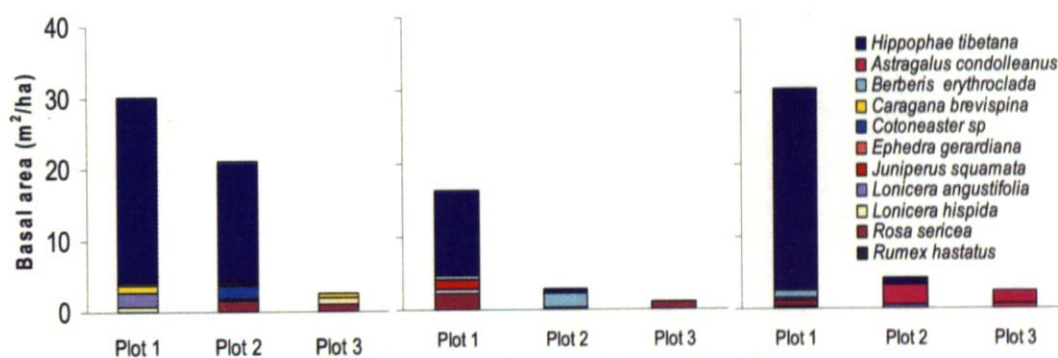


Fig. 23: Basal area of shrub in *H. tibetana* sites

4.2.5 Ground vegetation

There were very few shrub and tree in the *H. salicifolia* investigated plots. The volume of ground vegetation (Fig. 24) revealed that there was gradual decrease in volume along the slope from the plot near the water bodies towards upper slope in all the sites of Jharkot. Such steady trend was not observed in *H. salicifolia* sites except at Larjung. Volume of ground vegetation was high in Plot 2 of Kunjo and Plot 1 of Lete as compared to other plots in the respective site.

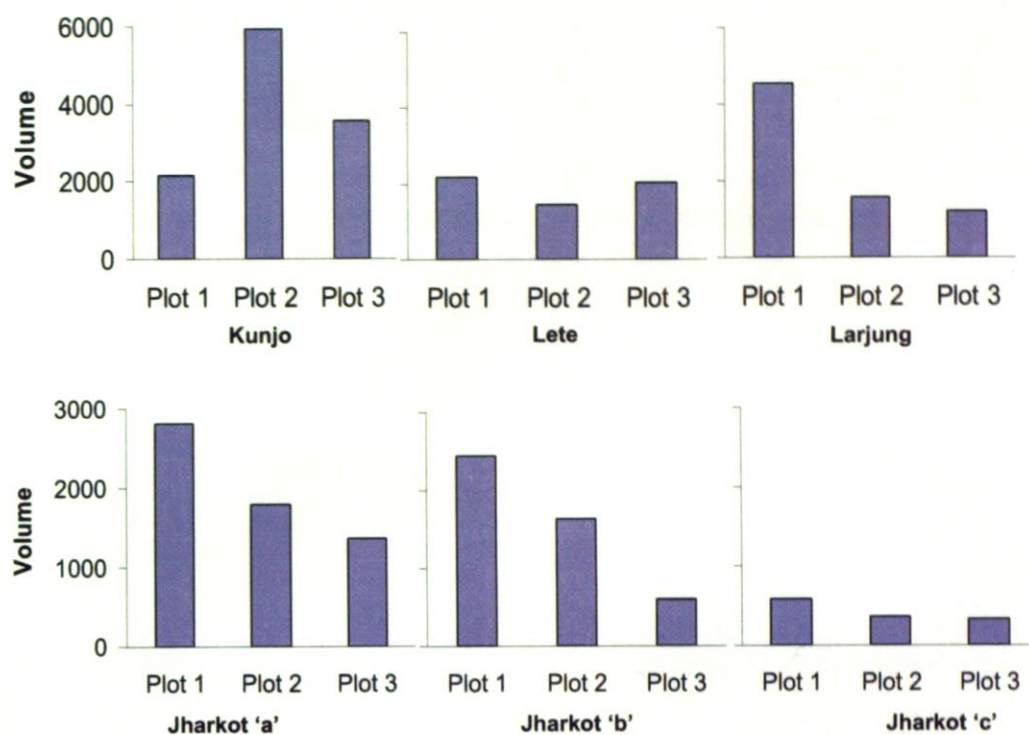


Fig. 24: Volume of ground vegetation

Species diversity of ground vegetation is illustrated in the Table 4. Diversity was increased along the slope from riverbank to upper slope in Kunjo. However, the value was high in Plot 2 of Lete and Larjung. The diversity decreased along the slope from the plot near the water bodies to upper slope in Jharkot 'a' and Jharkot 'b' but the diversity was high in Plot 2 of Jharkot 'c'.

Table 4: Species diversity of ground vegetation

Site	Plot no	Diversity (H')	Dominance (D)	Evenness (E)
Kunjo	1	2.09	0.36	0.35
	2	2.27	0.27	0.31
	3	2.51	0.28	0.27
Lete	1	2.48	0.24	0.47
	2	2.72	0.18	0.61
	3	2.52	0.23	0.49
Larjung	1	1.06	0.59	0.21
	2	1.98	0.34	0.43
	3	1.39	0.54	0.07
Jharkot 'a'	1	3.60	0.11	0.55
	2	2.94	0.16	0.57
	3	1.73	0.40	0.42
Jharkot 'b'	1	2.90	0.19	0.45
	2	2.24	0.28	0.35
	3	1.22	0.58	0.29
Jharkot 'c'	1	2.52	0.27	0.34
	2	2.74	0.19	0.60
	3	1.43	0.50	0.40

4.2.6 Soil properties

4.2.6.1 Physical properties

The texture of soil in majority of the surveyed plot was sandy loam (Fig. 25). Loamy sand was found in Plot 2 of Kunjo and Plot 1 of Larjung and loamy in Plot 2 at Jharkot 'b'. The percentage of sand was higher in *H. salicifolia* sites than Jharkot. Significant ($P \leq .05$) differences were found in the proportion of sand, silt and clay in Kunjo. However difference was not significant among the plots in Jharkot except clay content in Jharkot 'a'.

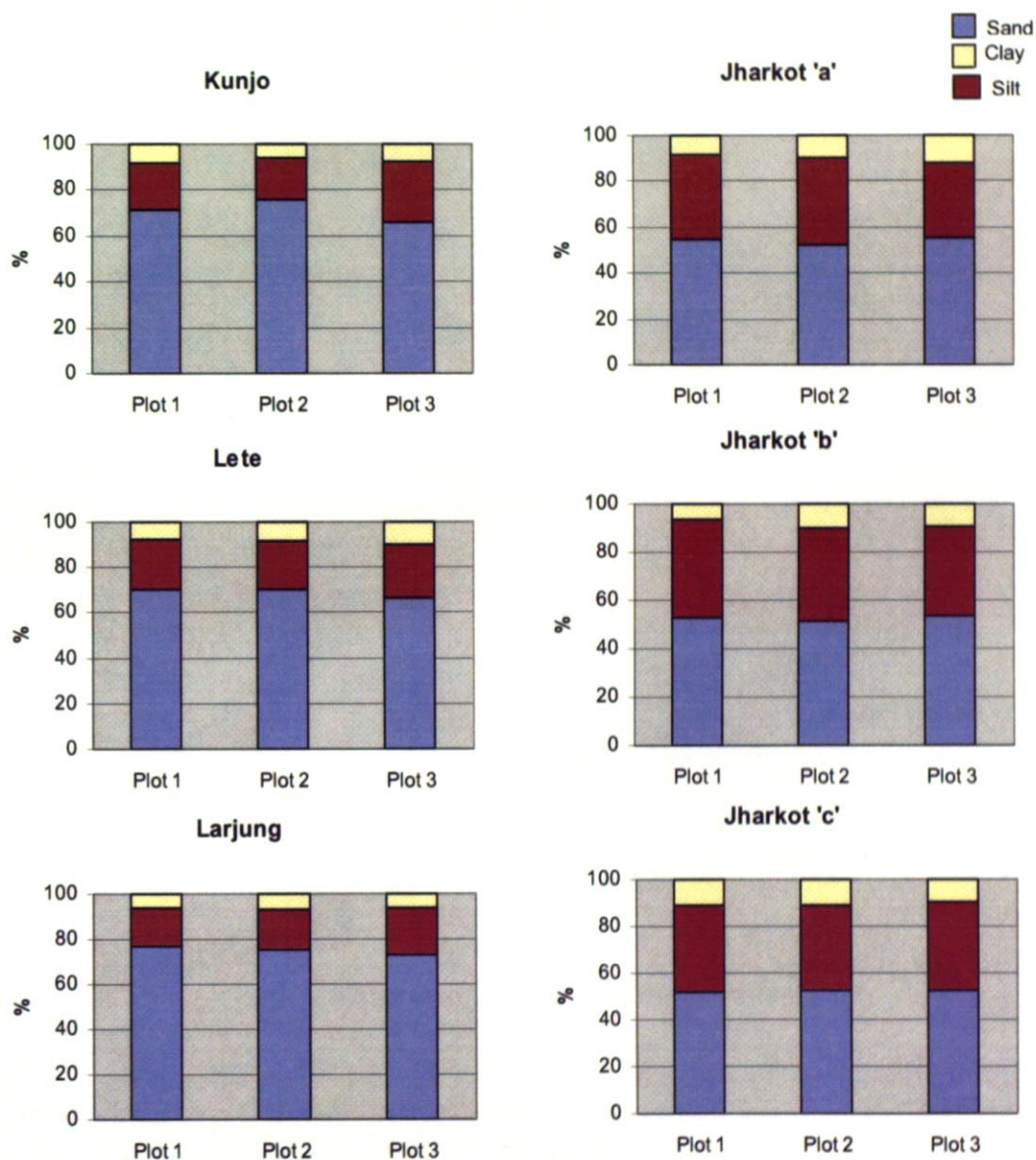


Fig. 25: Soil texture in different sites

4.2.6.2 Chemical properties

Both the species of *Hippophae* were found to grow on alkaline soil. The pH value decreased along the slope from river to upper slope in *H. salicifolia* sites (Fig. 26). On the other hand, the value increased from Plot 1 to Plot 3 in Jharkot. There was significant ($P \leq .05$) difference in pH value among the plots at Kunjo, Jharkot 'a' and Jharkot 'c'.

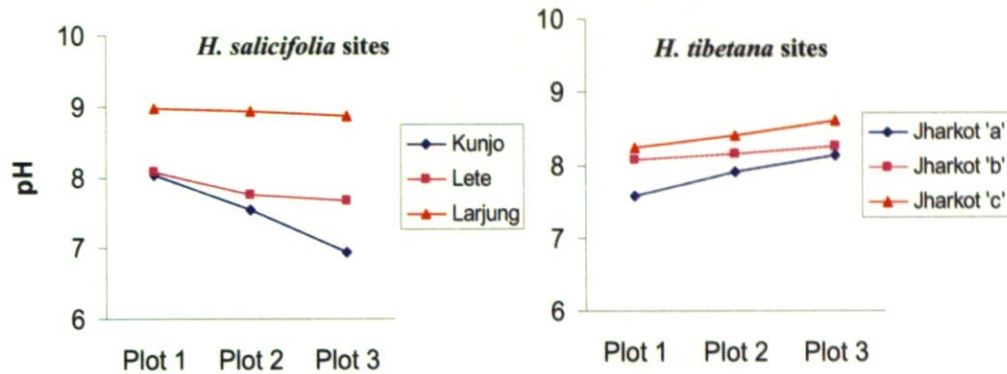


Fig. 26: Soil pH in different sites

There was gradual increase in the value of Electric conductivity from river slope to upper slope in *H. salicifolia* sites and declined from Plot 1 to Plot 3 in *H. tibetana* sites (Fig.27). Significant ($P \leq .05$) difference was found among the plots in Kunjo, Larjung, Jharkot 'a' and Jharkot 'c'.

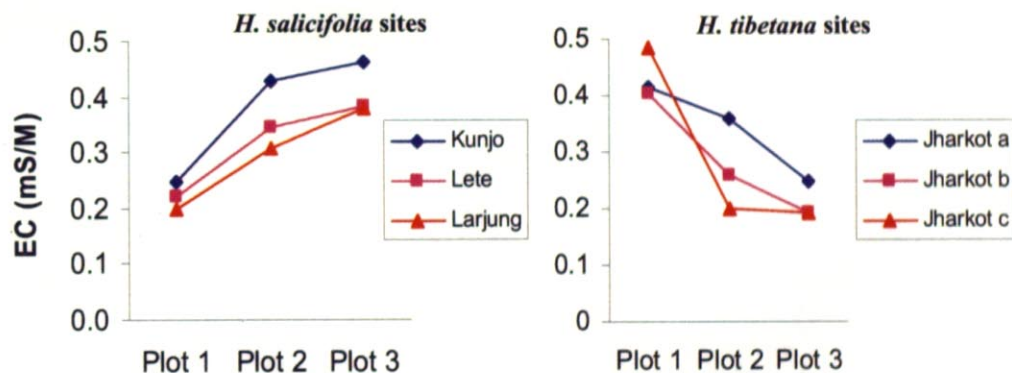


Fig. 27: Electric conductivity of soil in different sites

Carbon content in the soil is shown in the Fig. 28. There was variation in the percentage of carbon content in soil among the sites and plots in *H. salicifolia* studied area. The highest percentage was found in Plot 3 of Kunjo followed by Plot 2 and Plot 1. However, such trend was not found in Lete and Larjung. Plot 2 had high percentage and Plot 1 had least percentage in Lete. There was no great variation in carbon percentage among the three plots of Larjung. Significant difference ($P \leq .05$) was found among the plots in all sites except Larjung. Contrary to *H. salicifolia* sites, there was steady decrease in percentage of carbon from Plot 1 to Plot 3 in *H. tibetana* sites. The percentage was higher in Plot 1 of all sites and decreases gradually in Plot 2

and Plot 3. The highest percentage was recorded in Plot 1 of Jharkot 'a' and least in Plot 3 of Jharkot 'c'. The value had significant ($P \leq .05$) difference among the plots in all sites.

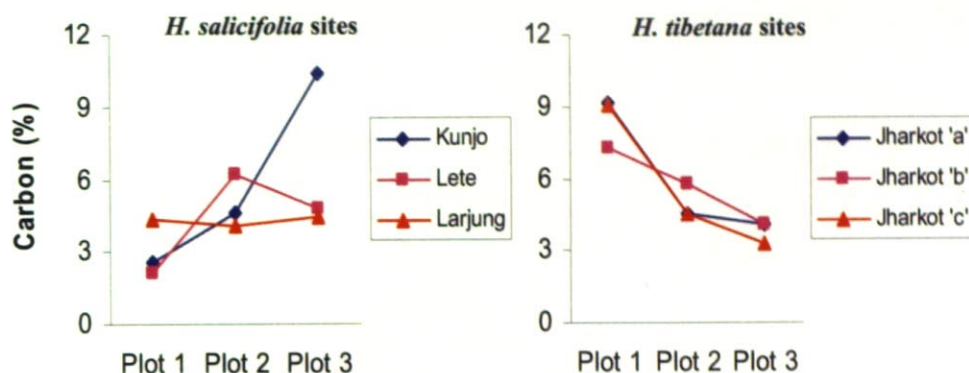


Fig. 28: Carbon content of soil in different sites

Variation in the percentage of nitrogen among the plots and sites was clearly observed in *H. salicifolia* sites (Fig. 29). Gradual increase was found from Plot 1 to Plot 3 in Kunjo and Lete. Soil of Plot 1 in all sites was poor in nitrogen as compared to middle and upper slope. The value was intermediary in middle slope. However in Larjung, differences were not distinct among the plots as other sites. On the other hand, gradual decrease was observed along the slope from Plot 1 to Plot 2 in Jharkot. The percentage was high in seabuckthorn occurring plots as compared to the seabuckthorn lacking plots. There was significant ($P \leq .05$) difference in the value of nitrogen among the plots in all the sites except Larjung.

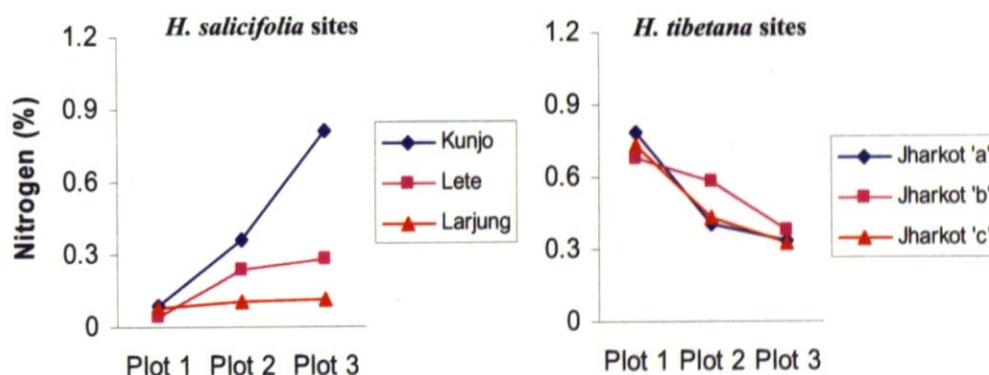


Fig. 29: Nitrogen content of soil in different sites

The ratio of carbon to nitrogen in the soil samples is shown in the Fig. 30. The ratio was high in Plot 1 in all sites of *H. salicifolia*. There was decrease in the value in Lete from river slope plot to upper slope plot. However in Kunjo and Larjung, remarkable differences in the value were not found between middle slope and upper slope. Among the sites the ratio value was higher in Larjung in all the plots. The value of C: N ratio in Plot 3 of Larjung was higher than Plot 1 of Kunjo. Significant ($P \leq .05$) difference was found at Kunjo, Lete and Jharkot 'a'. In Jharkot, the

variation was not so different among the plots within each site. The range of variation in the value in all plots was 12.41 (Plot 1 of Jharkot c) to 9.86 (Plot 2 of Jharkot b). There was no distinct trend along the plots. In Jharkot 'a' and Jharkot 'b', Plot 2 had less value than Plot 1 and Plot 3. However in Jharkot 'c', decreasing trend was found from Plot 1 to Plot 3.

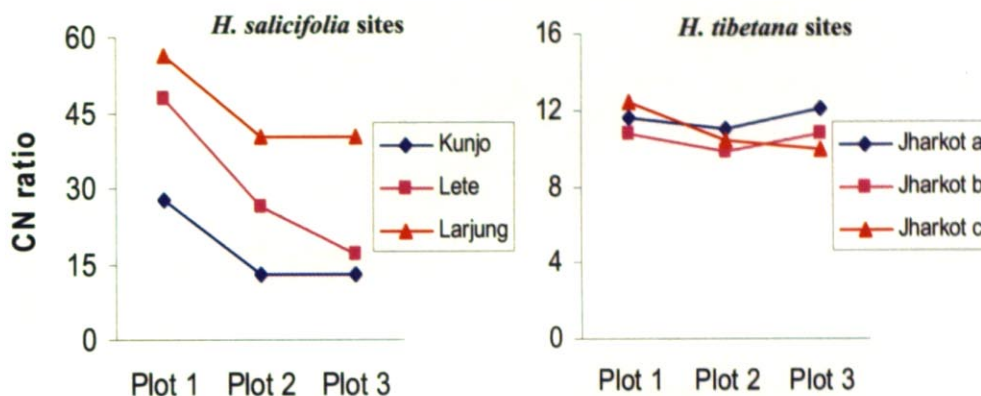


Fig. 30: Carbon Nitrogen ratio of soil in different sites

Clear differences could be seen in the amount of phosphorus between the seabuckthorn grown plots and plots without it in each site (Fig. 31). The amount was double or more in the upper slope plot than middle slope plots (e.g. the amount was 29.18 Kg/ha, 37.72 Kg/ha and 78.64 Kg/ha in Plot 1, Plot 2 and Plot 3 respectively in Kunjo) in *H. salicifolia* sites. The difference among the plots was significant ($P \leq .05$) in Lete and Larjung. Differences were found among the plots and sites in Jharkot. The amount was high in Plot 1 and then declined towards Plot 2 and 3 in all the sites. Huge differences in the amount of phosphorus were found in Plot 1 among the sites and the difference was lessening towards Plot 3. Significant ($P \leq .05$) difference was found among the plots in all sites.

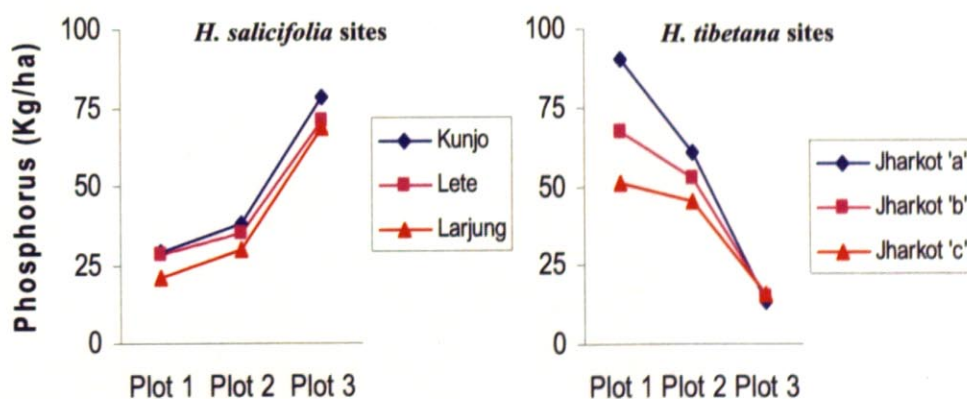


Fig. 31: Phosphorus content of soil in different sites

The amount of potassium varied with the plots at each site (Fig. 32). There was gradual increase in the amount of potassium from river slope to upper slope in *H. salicifolia* sites. The

amount was quite high in upper slope i.e. seabuckthorn-less plots and less towards middle slope and river slope. The trend was opposite in *H. tibetana* sites where the amount declined from Plot 1 towards Plot 2 and Plot 3. Significant ($P \leq .05$) difference was found among the plots in each site except Jharkot 'a' and Jharkot 'b'.

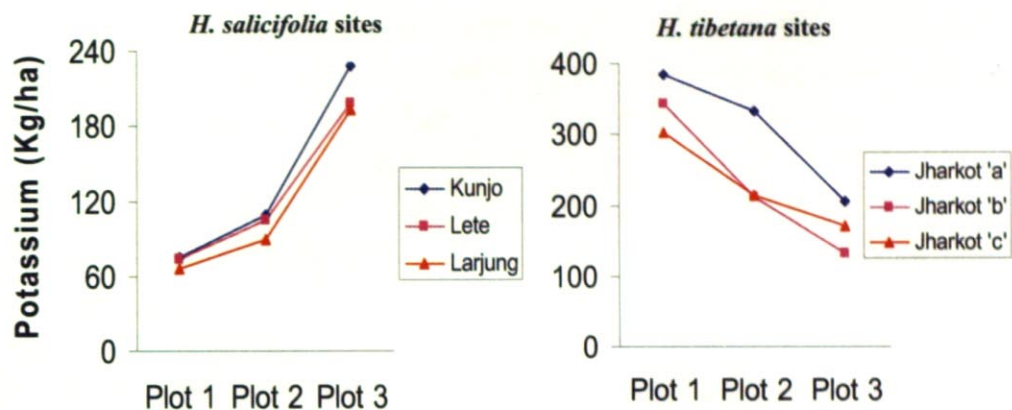


Fig. 32: Potassium content of soil in different sites

From the results of soil chemical properties, the soil development along the succession i.e. from Plot 1 to Plot 3 in *H. salicifolia* sites and from Plot 3 to Plot 1 in *H. tibetana* sites was confirmed.

5. Discussion

5.1 Distribution of seabuckthorn

The result of distribution of seabuckthorn in northwest Nepal revealed that the habitat for natural population of *H. salicifolia* is riverbank, mountain slope and mountain gullies from 2000 – 3850 m altitude and for *H. tibetana* is plain land near water bodies from 2900-4500 m. Lian *et al.* (1998) mentioned that the suitable altitude for *H. salicifolia* is 1500 – 3700 m and for *H. tibetana* 2700-5300 m. Our results partly agreed with those, however, the distribution of *H. tibetana* is within the range mentioned by them. We found *H. salicifolia* and *H. tibetana* in Dolpa, Mustang and Manang districts which represents rain shadow area that receives less than 300 mm precipitation per annum. It also contradicted with Huang and Yu (2006) who considered the suitable annual rainfall as 500- 600 mm. No record of *H. tibetana* in Mugu and Jumla probably due to physiographic condition of the districts that constituted few dry regions with relatively gentle hills. Mugu has large proportion of subtropical zones (Lilleso *et al.* 2000) which is not a suitable habitat for the growth of *H. tibetana*. In addition, *H. tibetana* preferred to colonize on the riversides in the dry habitats at an altitude of 3300 m to 4500 m which also scarce in Mugu and Jumla.

With the variation of longitude, associated species composition of seabuckthorn was also varying. Mustang and Manang district shared more common species and could be placed in one group from rest of the other district. The four districts i.e. Humla, Mugu, Dolpa and Jumla belonging to Karnali zone that has distinct bioclimatic region which does not have much similarity with rest of Nepal. It is more akin to Kashmir and its adjoining regions in the northwest Himalaya (Shrestha 1999). Thus, associated species composition of Karnali zone might differ from that of Mustang and Manang district.

5.2 Life form spectrum

Life form of plants has close relationship with the environmental factors. The result of this investigation did not show consistency in the composition of different life form in different plots investigated along the slope. However, high percentage of therophytes was found in Plot 2 of Kunjo and Plot 1 of Larjung in *H. salicifolia* studied sites. The sensitivity of herbaceous species to site conditions had led to their use as indicators of landform characteristics, disturbance history and altered edaphic and environmental conditions across the landscape and over time (Meilleur *et al* 1992). Those two plots with high percentage of therophytes were most affected by the human disturbance which could also be elucidating by the large number of cut stumps and foot trail along the plots. Therefore, *H. salicifolia* was found to regenerate in newly disturbed land in the riverbank. Diversity of life forms usually decreases with increasing altitude and one or two life forms remains at extreme altitudes (Pavon *et al* 2000). In this study, diversity of plant life form was high in *H. salicifolia* sites as compared to *H. tibetana* sites. The two sites were located in two different climatic zone of Nepal. The temperate zone is represented by *H. salicifolia* sites and

subalpine zone by Jharkot which resulted in the variation of life form in each site. The life form spectrum of Jharkot was dominated by hemicryptophytes. According to Raunkaier (1934), a hemicryptophytic phytoclimate corresponds to a cold-humid climate, typical of high latitude and high altitudes. Similar result was also found by Leos (2003).

Vegetation of the majority of plots in this study belonged to D4 (special mechanism has not developed for the dispersal of seed) and seeds are usually dispersed by the force of gravity. As the succession progresses, it is found that plants with no special device or censer dispersal are more frequent in the intermediary stages, while dispersal by ants and adhesion and in the digestive tract of animals increases later in the succession (Ulla 1993). Seabuckthorn which is the pioneer species also represents the intermediary position in the successional stages (Zhang 2005) and thus the plants occurred in each site might be dominated by disseminule form D4.

5.3 Size structure

Size structure can be taken as the indirect estimation of age. Size distribution of seabuckthorn in this study revealed that the river slope plot had individuals of less DBH and height class than middle slope. The size variation of seabuckthorn along the slope in this study was regarded to be age differences. River slope plot is unstable and highly vulnerable to disturbance such as landslide. In such disturbed condition, seabuckthorn is the pioneer colonizer woody plant to invade. On the other hand, middle slope is not vulnerable to disturbance than river slope and is more stable. Thus, aged plant existed in the stable plot and young individuals in the river slope. This trend of size class was varying in Larjung. Larjung was the river flood area and Plot 1 has affected by the flood during summer. The young seedlings and plants of the plot may be washed away by the flood and probably only large size plants that were not affected by flood could exist there. Thus, few large sizes seabuckthorn were found in Plot 1. Few individuals of seabuckthorn and few number other successor plants in Plot 3 indicated that the environment is not suitable for other successor to invade. This is also supported by less variation in carbon and nitrogen content of soil among plots.

H. tibetana confined in plot near the water sources had higher size class as compared to other plots. The upper slope area was too much dry for the growth of seabuckthorn. It indicates preference of water for growth and development of *H. tibetana* in the high altitude harsh environment.

5.4 Soil properties

Texture of soil in majority of plots was sandy loam. Sandy loam is the coarse texture soil that is poor in water and nutrient holding capacity. It suggested the capability of seabuckthorn growing in nutrient-poor soil. Soil pH is widely accepted as a dominant factor that regulates soil nutrient bioavailability, vegetation community structure, plant primary productivity and a range of soil processes including soil microbial community structure and activity (Robson, 1989). All the

investigated plots in this study had alkaline soil reaction except Plot 3 of Kunjo which was dominated by Pine and showed slightly acidic nature. Soil alkalinity and acidity did not seem to be limiting factor for the distribution of seabuckthorn (Lu 1992). Soil carbon has substantial effect on soil pH. Soils with high carbon contents have large capacities to release H^+ (Fisher and Binkley 2000). In accordance with this, pH and carbon value at Kunjo and Jharkot in this study show the same result.

Carbon, nitrogen, phosphorus and potassium were the major nutrients measured from the surface soil. Soil nutrients increased along the plot from river slope to upper slope except at Lete where the amount of carbon was less in Plot 3 than Plot 2. A significant positive relationship between soil nutrients and biomass indicated the interdependence between nutrient and biomass during succession (Reedy and Singh 1993). The trend of increase in the nutrient content in this research was also in accordance with the increase in basal area (Biomass) in each plot. Nitrogen is a major soil limiting nutrients and influences plant productivity remarkably. In this study, Plot 1 of all the *H. salicifolia* studied sites had low content of nitrogen than other plots of the same site. Inouye *et al.* (1987) stated that early stages of succession are characterized by low soil nitrogen and low plant biomass and later stages by higher nitrogen and high plant biomass as also observed in the present study. In general, carbon to nitrogen ratio is large in young stands and decrease with age (Fisher and Binkley 2000). Similar trend was also observed in this study where the gradual decrease in the ratio from river slope to upper slope in *H. salicifolia* sites.

5.5 Seabuckthorn in vegetation succession

Stainton (1972) mentioned that *H. salicifolia* forms almost pure thickets an acre or so in extent on newly formed alluvial gravel or on unstable slope which have water close to the surface and it often succeeded by poplar in more stable ground in Humla and Jumla area. The vegetation pattern along the slope in Mustang also reflected the similar condition, but the successor of seabuckthorn was pine. Pine was also considered as a pioneer tree species in the disturbed area and its persistence represents the situation similar to that of inhibitory model (holding the site against invasion by other tree species) (Reedy and Singh 1993). Seabuckthorn colonization in the study area represented the facilitation model of succession where colonization and growth of later species is facilitated by the condition created by earlier species. Thus, seabuckthorn later invaded by pine and represented the climax stage of vegetation in the area. The actinorhizal species are recognized as generally requiring high light conditions and rarely dominate the subcanopy of forest (Dawson 1990). Thus, seabuckthorn was not found to grow under canopy of pine in plot 3 along the slope. Jhang (2005) found that the major dominant plant of scrubland stage was *H. rhamnoides* with 90 % coverage in eastern Loess Plateau of China. *H. rhamnoides* is a pioneer woody species after herbs and which later replaced by tree species mainly *Pinus tabulaeformis*, *Quercus liaoungensis* and *Larix principis-rupprechtii*. This study also affirmed the representation of two different stages of succession along the slope in Mustang represented by *H. salicifolia*

stand along river and middle slope and pine stand. The appearance of pine in association with *Hippophae* in Lete represented the beginning of invasion. In both species, seabuckthorn was one of the first woody pioneers in the vegetation succession.

On the contrary, *H. tibetana* can not colonize upper slope of subalpine dry heath land. The successional gradient along the slope is opposite between the *H. salicifolia* sites and *H. tibetana* sites. *H. tibetana* was one of the latest- successional species which colonize the most fertile soil near water. Development of communities in the sub alpine region is quite slowly and does not attain a great stature of complicated structure due to the harsh environmental conditions.

5.6 Taxonomy and Ecology

The taxonomic treatment and relationship between the taxa in this genus remain in dispute. Based on the fruit morphology Lian *et al.* (1988) divided the genus into two broad groups namely Section Hippophae and Section Gyantsensis. Seabuckthorn species studied under this research represents both groups. Hippophae group comprises of *H. salicifolia* and most common seabuckthorn *H. rhamnoides*, and Gyantsensis comprises of *H. tibetana* and other species of *Hippophae*. Hippophae group tend to be drought resistant and perhaps occur earlier and is more primitive group and widely distributed. On the other hand, Gyantsensis is concentrated in small area above 3000 m a.s.l., tend to be dwarf and winter hardy and most evolved group in the genus. During the course of evolution, the height of Hippophae group plant become short, leaves become narrow, flower become simple to form new form i.e. Gyantsensis. Climatically Gyantsensis-occurring region is colder than Hippophae- occurring region. Though, *H. salicifolia* and *H. rhamnoides* were placed in the same group, close relationship was not found by either RAPD and cp DNA analyses (Bartish *et al.* 2000, 2002) or ITS analyses (Sun *et al.* 2002). RAPD analysis by Bartish *et al.* (2000) showed the relatively isolated position of *H. salicifolia* and *H. tibetana* and do not appear to be closely related neither to each other nor to any other taxa. Principal coordinate analysis showed the closeness of *H. tibetana* to *H. gyantsensis* but *H. salicifolia* clearly differentiated from other taxa (Bartish *et al.* 2000). Presumably, *H. salicifolia* and *H. tibetana* evolved independently from the common ancestor *H. rhamnoides*, the former to be tallest and the later to be dwarf.

6. Conclusion

Knowledge on habitat is indispensable for the management and sustainable utilization of plant resources. This study aims to explore the *H. salicifolia* and *H. tibetana* and to determine their habitat. Exploration of seabuckthorn in northwest Nepal reveals that the natural habitat of seabuckthorn includes fragile land of mountain slope, river bank and flat land. Both the species investigated under this study has affinity towards water sources.

The hierarchy in size along the slope unveiled that the regeneration potentiality of *H. salicifolia* was high towards the river slope. The soil condition of river slope was unstable and nutritionally very poor as compared to upper slope plots. It seems that in a course of time, seabuckthorn facilitate the growth of other successor and vanish in due course when overstory plants are well established in the habitat. On the other hand, *H. tibetana* prefers to grow on nutrient rich soil condition near water sources. A clear successional gradient was not found in *H. tibetana* due to the harsh environmental conditions where the development of communities is quite slow. Many studies has already been established the ecological status of *H. rhamnoides* which is the well known and widely distributed seabuckthorn in Eurasia. This study has support the ecological status attained by *H. rhamnoides* specially their role on vegetation succession.

Due to the physical and political constraints of the present study area, it was not possible to include all the factors that have major role in the distribution of seabuckthorn. Thus a detailed study incorporating major environmental factors is required to understand more precisely.

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Appendix 1: Plants and their life form in *H. salicifolia* sites

SN	Species	Family	Habit	Life form		Occurrence									
						Kunjo			Lete			Larjung			
				Raunkiaer	Disseminule	P1	P2	P3	P1	P2	P3	P1	P2	P3	P3
1	<i>Smilax aspera</i>	Liliaceae	Climber	Ph	D2				+						
2	<i>Carex rochebrunii</i>	Cyperaceae	Graminoid	He	D4				+	+	+	+	+	+	+
3	<i>Cynodon dactylon</i>	Poaceae	Graminoid	He	D4										+
4	<i>Achyranthes aspera</i>	Amaranthaceae	Herb	Th	D2										+
5	<i>Aechmananthera gossypina</i>	Acanthaceae	Herb	Th	D4	+									
6	<i>Ageratum conyzoides</i>	Compositae	Herb	Th	D1			+							
7	<i>Ajuga lobata</i>	Lamiaceae	Herb	He	D4							+			+
8	<i>Anaphalis busua</i>	Compositae	Herb	Th	D1	+									
9	<i>Anemone vitifolia</i>	Ranunculaceae	Herb	He	D4	+			+	+	+				
10	<i>Arisaema costatum</i>	Araceae	Herb	Th	D4			+		+					
11	<i>Artemisia brevifolia</i>	Compositae	Herb	Th	D4										+
12	<i>Artemisia gmelinii</i>	Compositae	Herb	Th	D4	+		+	+	+	+				
13	<i>Cannabis sativa</i>	Cannabaceae	Herb	Th	D4			+							+
14	<i>Cirsium wallichii</i>	Compositae	Herb	Th	D1	+						+	+		+
15	<i>Clematis montana</i>	Ranunculaceae	Herb	He	D1				+	+					
16	<i>Fragaria nubicola</i>	Rosaceae	Herb	He	D2			+	+	+	+				
17	<i>Geranium nepalense</i>	Geraniaceae	Herb	He	D3			+	+	+			+		
18	<i>Girardinia diversifolia</i>	Urticaceae	Herb	Th	D3			+							
19	<i>Gynura nepalensis</i>	Compositae	Herb	Th	D1							+			
20	<i>Heracleum lallii</i>	Umbelliferae	Herb	He	D1				+						
21	<i>Hydrocotyle nepalensis</i>	Araliaceae	Herb	He	D4							+			
22	<i>Impatiens racemosa</i>	Balsaminaceae	Herb	Th	D4	+									
23	<i>Oxalis corniculata</i>	Oxalidaceae	Herb	Th	D3			+	+	+	+	+	+	+	+
24	<i>Pedicularis gracilis</i>	Scrophulariaceae	Herb	Th	D4			+							
25	<i>Pedicularis hoffmeisteri</i>	Scrophulariaceae	Herb	Th	D4			+							
26	<i>Polygonatum cirrhifolium</i>	Liliaceae	Herb	He	D4			+							

	No.	Species	Fam.	Hab.	He	D4	+	-
27	Potentilla anserina	Rosaceae	Herb	He	D4			+
28	Ranunculus sp	Ranunculaceae	Herb	Th	D4		+	
29	Rheum acuminatum	Polygonaceae	Herb	Th	D4		+	
30	Rubia marjith	Rubiaceae	Herb	He	D4		+	
31	Salvia mibicola	Lamiaceae	Herb	He	D4		+	
32	Selaginella sp.	Silaginallaceae	Herb	Ch	D2		+	
33	Senecio chrysanthemoides	Compositae	Herb	Th	D1		+	
34	Solidago virga-aurea	Compositae	Herb	He	D1			+
35	Swertia chirayita	Gentianaceae	Herb	Th	D4		+	
36	Tanacetum atkinsonii	Compositae	Herb	Th	*		+	
37	Thalictrum virginatum	Ranunculaceae	Herb	Th	D4		+	+
38	Urtica dioica	Utricaceae	Herb	He	D4		+	
39	Berberis aristata	Berberidaceae	Shrub	Na	D2		+	
40	Berberis mucrifolia	Berberidaceae	Shrub	Na	D2		+	
41	Boehmeria platyphylla	Urticaceae	Shrub	Na	D1			+
42	Cotoneaster frigidus	Rosaceae	Shrub	Na	*			
43	Hypericum choisianum	Guttiferae	Shrub	Na	D4		+	
44	Inula cappa	Compositae	Shrub	Na	D1		+	
45	Prinsepia utilis	Rosaceae	Shrub	Na	*		+	
46	Rabdosis rugosa	Lamiaceae	Shrub	Na	D4		+	+
47	Rosa brunonii	Rosaceae	Shrub	Na	D2		+	
48	Rosa sericea	Rosaceae	Shrub	Na	D2			+
49	Rumex nepalensis	Polygonaceae	Shrub	Na	D4			
50	Sarcococca saligna	Boxaceae	Shrub	Na	*		+	
51	Sorbus microphylla	Rosaceae	Shrub	Na	D4			
52	Cinnamomum tamala	Lauraceae	Tree	Ph	D4		+	
53	Hippophe salicifolia	Eleagnaceae	Tree	Ph	D4		+	+
54	Juniperus indica	Cupressaceae	Tree	Ph	D4			+
55	Pinus wallichiana	Pinaceae	Tree	Ph	D4		+	+

Appendix 2: Plants and their life form in *H. tibetana* sites

[illegible]

29	<i>Stellera chamaejasme</i>	Thymeleaceae	Herb	He	D4	+	+			
30	<i>Swertia cordata</i>	Gentianaceae	Herb	Th	D4		+		+	
31	<i>Swertia racemosa</i>	Gentianaceae	Herb	Th	D4	+				
32	<i>Tanacetum aikinsonii</i>	Asteraceae	Herb	Th	*	+	+	+		+
33	<i>Taraxum</i> sp	Asteraceae	Herb	He	D1		+		+	
34	<i>Thalictrum foetidum</i>	Ranunculaceae	Herb	Th	D4	+				
35	<i>Astragalus candolleanus</i>	Leguminosae	Shrub	He	D4				+	+
36	<i>Berberis erythroclada</i>	Berberidaceae	Shrub	Na	D2	+	+		+	
37	<i>Caragana brevispina</i>	Leguminosae	Shrub	Na	D3	+				
38	<i>Cotoneaster</i> sp	Rosaceae	Shrub	Na	D2	+				
39	<i>Ephedra Gerardiana</i>	Ephedraceae	Shrub	Na	D2					+
40	<i>Hippophae tibetana</i>	Elaeagnaceae	Shrub	Na	D4	+	+		+	
41	<i>Juniperus squamata</i>	Cupressaceae	Shrub	Na	D4		+			
42	<i>Lonicera angustifolia</i>	Caprifoliaceae	Shrub	Na	D2	+	+	+	+	+
43	<i>Lonicera hispidula</i>	Caprifoliaceae	Shrub	Na	D2	+				
44	<i>Rosa sericea</i>	Rosaceae	Shrub	Na	D2	+	+	+	+	+

Where,

Ph. Phanerophyte; Na, Nanophanerophyte; Ch- Chamaephyte; He, Hemicryptophyte; Th, Therophyte

D1- Disseminated widely by wind and water;

D2 - Disseminated attaching with or eaten by animals and man;

D3 - Disseminated by mechanical propulsion of dehiscence of fruits;

D4 - Having no special modification for dissemination and

D5 - Not producing seeds

* Not known

P1- Plot 1, P2- Plot 2 and P3- Plot 3

Appendix 3: Soil variables

Sites	Plots	pH	Carbon (%)	Nitrogen (%)	C:N	Phosphorus (kg/ha)	Potassium (kg/ha)	EC (mS/M)	Sand (%)	Silt (%)	Clay (%)
Kunjo	1	8.024	2.5488	0.0922	27.6592	29.18	75.14	0.25	71.00	20.70	8.30
	2	7.542	4.6621	0.3595	12.9680	37.72	108.60	0.43	75.62	18.12	6.26
	3	6.932	10.4371	0.8095	12.8938	78.64	228.00	0.46	65.74	27.04	7.22
Lete	1	8.08	2.0975	0.0437	48.0034	28.72	74.20	0.22	70.00	22.46	7.54
	2	7.76	6.1864	0.2355	26.2686	35.00	104.95	0.35	70.46	21.44	8.10
	3	7.66	4.7564	0.2809	16.9298	70.70	198.72	0.38	66.70	23.12	10.18
Larjung	1	8.98	4.3980	0.0779	56.4744	21.03	66.64	0.20	76.96	17.06	5.98
	2	8.94	4.1305	0.1026	40.2694	30.17	89.72	0.31	75.24	18.16	6.60
	3	8.86	4.4765	0.1108	40.4037	68.89	192.89	0.38	73.08	21.12	5.80
Jharkot 'a'	1	7.57	9.1291	0.7850	11.6292	90.74	383.80	0.41	54.66	37.16	8.18
	2	7.9	4.5190	0.4093	11.0409	60.96	333.14	0.36	52.20	38.30	9.50
	3	8.134	4.0729	0.3366	12.0988	13.32	206.40	0.25	55.06	33.16	11.74
Jharkot 'b'	1	8.08	7.3062	0.6791	10.7586	67.44	342.72	0.40	52.84	40.62	6.54
	2	8.16	5.7799	0.5864	9.8574	52.82	212.20	0.26	51.38	38.80	9.82
	3	8.26	4.1081	0.3803	10.8015	14.62	131.44	0.19	53.22	37.54	9.24
Jharkot 'c'	1	8.24	9.0687	0.7308	12.4095	50.76	302.00	0.48	52.06	37.10	10.84
	2	8.4	4.5165	0.4341	10.4050	45.40	215.00	0.20	52.68	36.48	10.84
	3	8.62	3.2677	0.3293	9.9218	15.62	170.12	0.19	52.42	38.02	9.56